Digitized by the Internet Archive
in 2022 with funding from
Kahle/Austin Foundation

https://archive.org/details/studyoftimefacto0000hora

Bulletin 223 October, 1929

A Study of the Time Factor in Egg Production

by
HORACE ATWOOD

UNIVERSITY OF ARIZONA LIBRARY

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

UNIVERSITY OF ARIZONA
630.72
W51
LIBRARY

AGRICULTURAL EXPERIMENT STATION STAFF

JOHN R. TURNER, Ph. D., LL. D. ..... President of the University
F. D. FROMME, Ph. D. ..... Dean and Director
GERALD JENNY, M. S. ..... Agricultural Editor
JOHN C. JOHNSTON ..... Chief Clerk

AGRONOMY AND GENETICS

R. J. Garber, Ph. D.
Agronomist and Geneticist

E. P. Deatrick, Ph. D.
Associate Agronomist

W. H. Pierre, Ph. D.
Associate Agronomist

T. C. McIlvaine, Ph. D.†
Assistant Agronomist

D. R. Dodd, B. S.
Assistant Agronomist

M. M. Hoover, M. S.
Assistant Agronomist

H. K. Rowley, M. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, D. Sc.
Animal Husbandman

Chas. V. Wilson, M. S.
Assistant Animal Husbandman

J. H. Longwell, M. A.
Assistant Animal Husbandman

J. H. Rietz, D. V. M.
Associate Veterinarian

R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman

R. S. Glasscock, M. S.**
Assistant in Veterinary Science

CHEMISTRY

R. B. Dustman, Ph. D.
Agricultural Chemist

Chas. E. Weakley, Jr., B. A.
Assistant Chemist

L. P. Hansen, Ph. D.
Assistant Chemist

T. B. Leith, M. S.**
Assistant Chemist

Leland Shriver, B. S. Ch. E.
Assistant in Agricultural Chemistry

DAIRY HUSBANDRY

H. O. Henderson, Ph. D.
Dairy Husbandman

L. M. Thurston, Ph. D.
Assistant Dairy Husbandman

K. S. Morrow, M. S.
Assistant Dairy Husbandman

L. F. Sutton, B. S. Agr.‡
Assistant Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist

W. E. Rumsey, B. S.**
State Entomologist

Edwin Gould, B. S. Agr.
Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist

F. D. Cornell, Jr., M. S.
Assistant Farm Mechanician

W. W. Armentrout, M. S.
Assistant Farm Economist

R. O. Stelzer, B. S.
Assistant in Farm Economics

HOME ECONOMICS

Rachel H. Colwell, M. A.
Home Economist

Hazel C. Cameron, M. A.
Research Specialist in Nutrition

HORTICULTURE

H. E. Knowlton, Ph. D.
Horticulturist

K. C. Westover, M. S. Agr.
Assistant Horticulturist

M. B. Hoffman, M. S.
Assistant in Horticulture

W. N. McCubbin, M. A.
Assistant in Horticulture

PLANT PATHOLOGY

C. R. Orton, Ph. D.
Plant Pathologist

Anthony Berg, M. S.
Associate Plant Pathologist

L. H. Leonian, Ph. D.
Associate Plant Pathologist

F. J. Schneiderhan, M. S.
Associate Plant Pathologist

E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr.
Poultry Husbandman

T. B. Clark, B. S. Agr.
Assistant in Poultry Husbandry

---

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-Station, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

*A Study of the Time Factor in Egg Production**

by HORACE ATWOOD

WHEN a bird lays for several days in succession the first egg is usually the heaviest. Generally there is a gradual decrease in the weight of the eggs toward the end of the series, the last egg being the lightest. Then, after the bird has ceased to lay for one or more days, another series of eggs is started beginning with a heavy egg, and so on. A series of eggs so laid is called a cycle or clutch.

The first egg of a cycle usually is laid relatively early in the day and the remainder of the eggs in the cycle generally are laid later and later respectively on following days. An example of an egg cycle showing the weights of the eggs and the time of laying is shown in Table 1.

TABLE 1.—Weight of Eggs and Time of Laying for One Cycle by Bird No. 124. (August, 1926)

Date of Laying	Time of Laying	Weight of Eggs in Grams	Interval
Aug. 1	did not lay	none	---------
Aug. 2	9 a. m.	55.7	---------
Aug. 3	11 a. m.	53.6	26 hours
Aug. 4	1 p. m.	53.4	26 hours
Aug. 5	3 p. m.	51.5	26 hours
Aug. 6	did not lay	none	---------

It is evident from Table 1 that the normal laying period for this bird during the time under consideration was 26 hours.

The length of the interval from the laying of one egg to the laying of another in the same cycle probably closely depends upon the activity of the physiological processes associated with egg production. If this be true the intervals may be used as a measure of the activity of the processes, and an understanding of these intervals may prove

*Submitted for publication June, 1927.

108507

to be of importance in connection with feeding and breeding experiments.

Source and Method of Handling Data

During August, 1926, 172 White Leghorns in their first laying year were trapped hourly on the hour beginning at 8 a. m. and ceasing at 5 p. m. Particular care was taken to record all eggs laid during each interval. The birds laid during the month 3,516 eggs,—an average production of 20.44 eggs each.

In handling the data all eggs laid during any hourly interval were considered as though they were laid at the expiration of that interval, and in this discussion only those intervals have been considered when eggs were laid on consecutive days.

Correlations and deviations have been computed by the method proposed by Phillips,* and the probable error of the mean has been calculated from the customary formula.

The following discussion is a summary of the results obtained from the statistical examination of the data.

Cycles Consisting of Two Eggs Only

During the month 139 birds laid 485 two-egg cycles. The mean interval between the time of laying the first egg and the time of laying the second egg was one day plus 4.033±.031 hours, or practically 28 hours. The standard deviation of the intervals was 1.022±.022 hours.

Cycles Consisting of Three Eggs

During the month 137 birds laid a total of 355 three-egg cycles. The mean length of the intervals and the standard deviation of the intervals are given in Table 2.

TABLE 2.—Mean Length of Intervals and Standard Deviation of Intervals in Three-Egg Cycles

Period between	Mean Interval *(One Day Omitted)*	Standard Deviation of Intervals
First and second eggs	2.479±.035 hours	.968±.025
Second and third eggs	3.208±.032 hours	.886±.022
All intervals	2.844±.025 hours	.996±.018

The mean interval between the second and third eggs was materially longer than the interval between the first and second eggs. Also the mean of all the intervals in the three-egg cycles was slightly

Monthly Weather Review, March, 1922, p. 135.

more than one hour shorter than the mean of the intervals in the two-egg cycles, showing that egg production moves at a faster pace in the longer cycles.

Cycles Consisting of Four Eggs

During the month 82 birds laid a total of 137 four-egg cycles. The mean length of the intervals and the standard deviation of the intervals are given in Table 3.

TABLE 3.—Mean Length of Intervals and Standard Deviation of Intervals in Four-Egg Cycles

Period between	Mean Interval (One Day Omitted)	Standard Deviation of Intervals
First and second eggs	1.664±.058 hours	1.012±.041
Second and third eggs	1.548±.065 hours	1.125±.046
Third and fourth eggs	2.569±.061 hours	1.052±.043
All intervals	1.927±.039 hours	1.159±.027

In the four-egg cycles the shortest mean interval was between the second and third eggs, and the longest mean interval was between the last two eggs in the cycles. It is to be observed also that the mean of all the intervals is smaller than in the two-egg or three-egg cycles.

Cycles Consisting of Five Eggs

During the month 36 birds laid 46 five-egg cycles. Table 4 records the mean intervals and the standard deviation of these intervals.

TABLE 4.—Mean Length of Intervals and Standard Deviation of Intervals in Five-Egg Cycles

Period between	Mean Interval (One Day Omitted)	Standard Deviation of Intervals
First and second eggs	1.478±.124 hours	1.426±.100
Second and third eggs	0.913±.109 hours	1.099±.077
Third and fourth eggs	1.109±.102 hours	1.026±.072
Fourth and fifth eggs	2.435±.162 hours	1.624±.115
All intervals	1.484±.071 hours	1.437±.051

In the cycles consisting of five eggs the greatest mean interval was between the last two eggs in the cycles, and the intervals between the second and third eggs and between the third and fourth eggs were significantly shorter than the intervals at either extremity of the cycles. The standard deviations of all intervals were somewhat greater than in the case of the four-egg cycles.

Cycles Consisting of Six Eggs

During the month 17 birds laid 21 six-egg cycles. The mean intervals and the standard deviation of these intervals are recorded in Table 5.

TABLE 5.—Mean Length of Intervals and Standard Deviation of Intervals in Six-Egg Cycles

Period between	Mean Interval *(One Day Omitted)*	Standard Deviation of Intervals
First and second eggs	1.619±.116 hours	.785±.082
Second and third eggs	1.191±.133 hours	.906±.094
Third and fourth eggs	—0.238±.340 hours	2.307±.240
Fourth and fifth eggs	0.667±.205 hours	1.392±.145
Fifth and sixth eggs	2.810±.128 hours	.871±.091
All intervals	1.210±.251 hours	1.705±.178

Agreeing with the results obtained in the shorter cycles, the longest mean interval was between the last two eggs in the cycles, and the shortest intervals were between the eggs in the middle of the cycles. Also in these cycles the mean of all intervals was shorter than in the cycles consisting of a smaller number of eggs.

The standard deviations indicate that there was greater variability in the length of the intervals toward the center of the cycles than at either extremity. Why this should be so is not apparent.

Cycles Consisting of Seven Eggs

During the month six birds laid six cycles consisting of seven eggs each. Table 6 gives the mean intervals and the standard deviation of these intervals.

TABLE 6.—Mean Length of Intervals and Standard Deviation of Intervals in Seven-Egg Cycles

Period between	Mean Interval *(One Day Omitted)*	Standard Deviation of Intervals
First and second eggs	1.833± .130 hours	.473±.092
Second and third eggs	2.000± .275 hours	1.000±.195
Third and fourth eggs	0.500± .741 hours	2.693±.524
Fourth and fifth eggs	—2.333±1.014 hours	3.682±.717
Fifth and sixth eggs	1.500± .264 hours	.957±.186
Sixth and seventh eggs	3.000± .159 hours	.577±.112
All intervals	1.083± .293 hours	2.607±.208

In the cycles consisting of seven eggs the longest mean interval

was between the last two eggs in the cycles, and agreeing with the results obtained with the shorter cycles, the shortest mean intervals were found in the middle of the cycles, the interval between the fourth and fifth eggs being less than twenty-four hours. Also agreeing with the results obtained with the six-egg cycles, there was greater variability in the length of the intervals toward the center of the cycles than at either extremity.

Cycles Consisting of Eight or More Eggs

As the number of cycles consisting of eight or more eggs is too small to give reliable averages of the intervals between the various eggs in the cycles, the mean of all the intervals in these longer cycles has been computed and the results are presented in Table 7. Also for purposes of comparison the means of all intervals and standard deviations of intervals in the shorter cycles are brought together in this table.

TABLE 7.—Mean Length of Intervals and Standard Deviation of These Intervals in Cycles Containing Two or More Eggs

Length of Cycle	Number of Birds	Number of Cycles	Mean Length of Intervals in Hours	Standard Deviation of Intervals
2 eggs	139	485	24+4.033±.031	1.022±.022
3 eggs	137	355	24+2.844±.025	.996±.018
4 eggs	82	137	24+1.927±.039	1.159±.027
5 eggs	36	46	24+1.484±.071	1.437±.051
6 eggs	17	21	24+1.210±.251	1.705±.178
7 eggs	6	6	24+1.083±.293	2.607±.208
8 eggs	3	4	24+ .571±.211	1.657±.149
9 eggs	1	1	24+ .750±.733	3.072±.518
10 eggs	3	3	24+ .407±.108	.828±.076
11 eggs	2	2	24+ .700±.291	1.926±.205
26 eggs	1	1	24+ .160±.079	.731±.070

Table 7 shows that as the cycles became longer the mean interval between the laying of one egg and the laying of the next egg in the cycle became shorter. For cycles consisting of two eggs only, the mean interval was approximately 28 hours, and as the cycles became longer there was a reasonably uniform decrease in the length of the intervals until in the one cycle consisting of 26 eggs the interval was approximately 24 hours.

A study of the results shows that the mean interval between the last two eggs in the cycles was greater than any other mean interval.

Also, at or about the center of the cycles the mean intervals were shorter than at either end, indicating that egg production is speeded up after the cycle has been started and that after the middle of the cycle has been reached this acceleration is succeeded by a slackening or retardation.

Effect of Bird Age on Length of Intervals

During August, 1927, as well as during August of the preceding year the average interval between the laying of successive eggs was determined for each of 132 birds that laid during each month. The unweighted mean interval for August, 1926, was found to be one day plus 2.6761±.0539 hours, and for August, 1927, the interval was one day plus 3.7008±.0506 hours. The difference between these two mean intervals, 1.0247±.0739 hours, apparently represents the mean additional time required by the older birds at that particular season of the year to produce an egg after a cycle has been started. The standard deviation of the intervals was practically the same in both instances, being .918±.038 for the pullets and .862±.036 when they were one year older.

Correlation of Intervals at Different Ages

It is interesting to determine whether the average length of interval between the laying of successive eggs is a persistent character of a bird or merely temporary in its nature. To throw light on this question the correlation between the average intervals for each bird at the two different ages was calculated and was found to be +.578±.039. This correlation is positive and significant and indicates that the interval between the laying of successive eggs is a reasonably definite and fixed character.

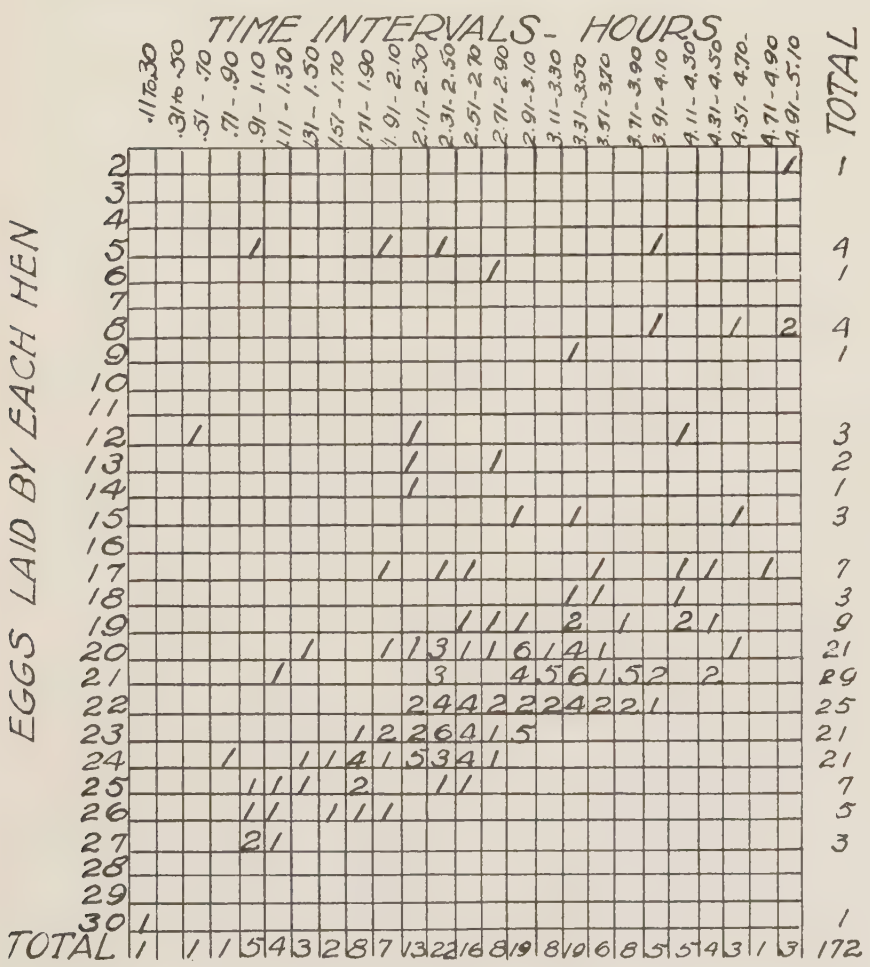
Correlation of Mean Intervals and Annual Egg Production

If a close relationship should exist between the average interval for a few cycles and the number of eggs that a bird will lay in a year, it would afford information from which the future productivity of a bird could be predicted. The sum was obtained of all of the intervals in hours between eggs laid on consecutive days in all cycles for each bird in the test for the month of August, 1926. This sum divided by the number of intervals gave the average duration of each interval for each bird for the month. The average interval for each bird was then correlated with the number of eggs laid by each bird for the pullet year and the coefficient was found to be —.413±.043. The coefficient

is negative and significant and shows that the shorter the average interval for August, the better the egg production for the year.

The mean of the 172 average intervals was found to be one day plus 2.814±.048 hours, and the standard deviation of these intervals was .923±.048.

TABLE 8.—Correlation Table Showing Distribution of Egg Production and Intervals between Successive Eggs in Cycles for August, 1926



$r = -.420 \pm .041$

Correlation of Average Intervals and Monthly Egg Production

The coefficient of correlation was computed also between the average time interval for the month of August for each bird and the egg production of each bird for that month. It was found to be —.420±.041. This coefficient also is negative and significant and shows that the shorter the average time interval between the laying of successive eggs in the cycles for August, the better the egg production for that month. The data used in calculating this coefficient are shown in Table 8. (See page 9).

Summary and Conclusions

When a bird lays for several days in succession the first egg of the cycle or clutch generally is laid relatively early in the forenoon. The remainder of the eggs is laid later and later on succeeding days, the last egg of the cycle being laid relatively late in the afternoon. Then the bird ceases to lay for one or more days, and when a new cycle is started, again the first egg is laid early in the forenoon, and so on. The length of the interval between the laying of successive eggs is fairly uniform for any particular bird.

The data examined apparently justify the following conclusions:

The longer the cycle, the shorter are the intervals between the laying of successive eggs.

The interval between the laying of the last two eggs in a cycle is usually greater than any other interval in the cycle.

The intervals between the laying of eggs at or about the middle of the cycles are shorter than the intervals at either extremity.

As the birds become older the intervals between the laying of successive eggs become longer.

The shorter average intervals between the laying of successive eggs are usually associated with the more prolific layers.

Publications of this Station will be mailed free to any citizen of West Virginia upon written application. Address Director of the West Virginia Agricultural Experiment Station, Morgantown, West Virginia.

APPENDIX

Time of Laying Used to Check Trap Nest Records

The high degree of regularity with which birds lay later and later in the day on succeeding days affords means by which trap nest records may be checked with a high degree of accuracy when the time of laying is recorded for each day. For example, suppose that the records of egg production and time of laying for a bird were as follows: 8:00 a. m., 10:00 a. m., 11:00 a. m., 12:00 m. and 1:00 p. m. If on the day following the last record an inspector should trap that particular bird at 9:00 a. m. he would know quite definitely that the record for the preceding day was wrong and that either a mistake had been made or the record had been intentionally falsified.

Bibliography

TURPIN, G. M., THE NESTING HABITS OF THE HEN. Iowa Agr. Exp. Sta. Bul. 178, May, 1918.

GOODALE, H. D., ON THE RHYTHM OF EGG PRODUCTION. Jour. Amer. Assn. Instr. and Invest. in Poult. Husb., 1:18, 1915.

PATTERSON, C. T., CYCLES AND RHYTHM OF EGG PRODUCTION. Jour. Amer. Assn. Instr. and Invest. in Poult. Husb., 3:16:20, 1916.

ATWOOD, H., AND WEAKLEY, C. E. JR., CERTAIN CHARACTERISTICS OF HEN EGGS. W. Va. Agr. Exp. Sta. Bul. 166, 1917.

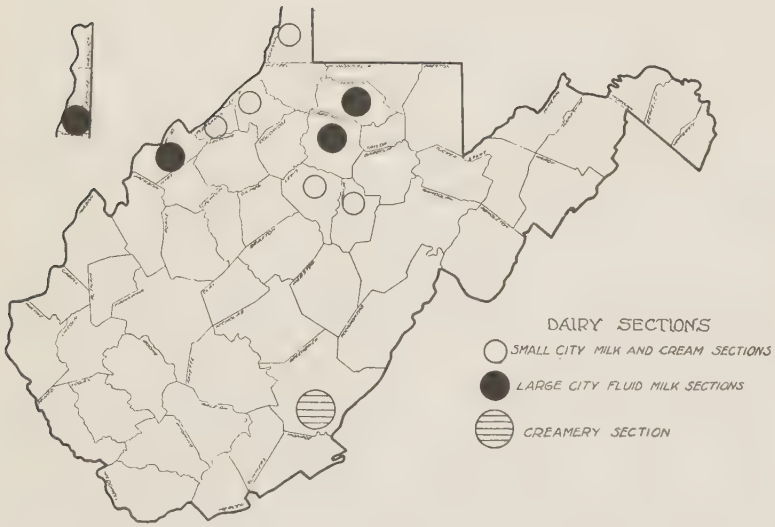
ATWOOD, H., THE WEIGHT OF EGGS IN CONNECTION WITH THE TIME OF DAY WHEN THEY ARE LAID. Poultry Science, VI, 3:108-109, 1927.

Bulletin 224 November, 1929

LIBRARY

The Cost of Raising Dairy Cows in West Virginia

by PAUL A. EKE



Typical Dairy Sections of West Virginia

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

SUMMARY

The range in the net cost per head until time of freshening for grade and native heifers was approximately $50 to $200. The most common costs were from $90 to $130 for spring calves and from $70 to $110 for fall calves.

The range in the net cost per head until time of freshening for purebred heifers was from approximately $70 to $240. The most common costs were from $90 to $150 for spring calves and from $90 to $130 for fall calves.

From 50 to 60 percent of the cost of raising occurred during the first year. By far the greater part of the cost for the first year occurred during the milk-feeding period.

For all classes of heifers approximately 77 percent of the total cost was expended for feed alone, from 11 to 14 percent for labor, and from 9 to 12 percent for all other costs.

The creamery section showed the lowest costs for raising grade and native heifers, followed in order by the large city fluid milk sections and the small city milk and cream sections.

Heifers born in the spring cost more to raise than heifers born in the fall. The difference in the average costs until time of freshening ranged from 4.3 percent for purebreds to 7.6 percent for grade and native heifers.

By excluding the extremely high and low-cost herds it is found that the approximate difference in net costs per head of purebred and of grade and native herds was $20 more per head for purebred heifers. However, the difference in the average net costs of all herds was approximately $40 more per head for purebred heifers.

The following factors should be considered in deciding to raise or buy replacements for the dairy herd:

1. The danger of infectious diseases.
2. The risks of buying as well as of raising poor producers.
3. The difference in cost of the two methods available for obtaining replacements for the dairy herd.

*The Cost of Raising Dairy Cows in West Virginia**

by PAUL A. EKE†

DAIRYMEN in West Virginia have been much concerned about the problem of raising heifers for herd replacements. Many important questions have arisen about this problem. In an endeavor to answer these questions an investigation was made of the costs incurred by 128 dairymen in ten dairy sections of the state. Forty-four of the herds consisted mainly of purebred stock and the other eighty-four herds of grade and native stock. The figure on the cover page gives the location of these sections.

A summary and statistical analysis of the estimates given by the dairymen has answered some of the more important questions.

The cost estimates obtained were for the summer of 1925 and winter of 1926, and for this reason give only an approximation of what may be the costs at present or in the future.

The value of the study consists in giving (1) the approximate costs of raising heifers in a number of sections of West Virginia; (2) the percentage of the total cost which occurred during successive seasons and years; (3) the percentage of the total cost due to feed, labor and other cost items; (4) a comparison of the costs for the different sections which were visited; (5) a comparison of the costs of raising spring and fall calves; (6) a comparison of the costs of raising purebred and "grade and native" heifers; and (7) the factors which influence the decision of dairymen to raise or buy herd replacements.

Cost of Raising Heifers

The cost of raising grade and native heifers differed rather markedly from the cost of raising purebreds. Figure 1 gives the range in net costs of raising grade and native heifers to two years of age, while Figure 2 gives the net costs till time of freshening. Figure 3 gives the range in net costs of raising purebred heifers until time of freshening. Table 1 gives the actual number of herds which fell in certain cost groups.

*Submitted for publication September, 1927.

†Resigned April, 1929.

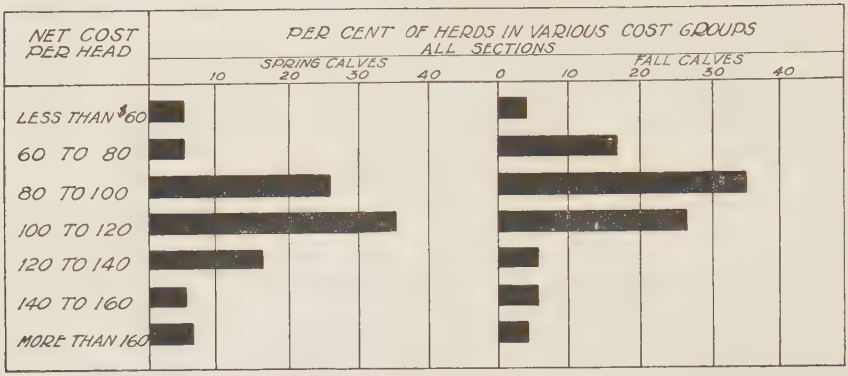


Figure 1.—Range and Distribution of Net Costs per Head to Two Years of Age for Grade and Native Herds

Figure 1 shows that the net cost per head to two years of age for grade and native spring and fall heifer calves in the three types of dairy sections studied varied from approximately $50 to $200. In the case of the spring calves 77 percent of the herds fell in three groups which showed a cost range of from $80 to $140. In the case of the fall calves 79 percent of the herds fell in three groups which showed a cost range of from $60 to $120.

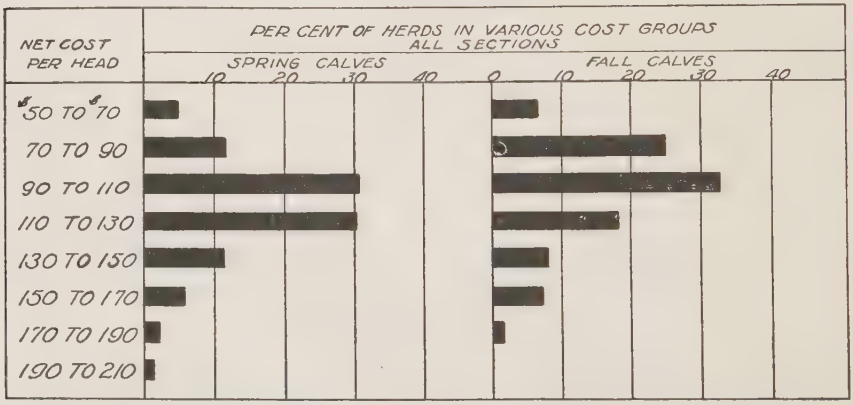


Figure 2.—Range and Distribution of Net Costs per Head till Time of Freshening for Grade and Native Herds

Figure 2 shows that the net cost per head till time of freshening for grade and native spring and fall heifer calves varied from approximately $50 to $210. In the case of the spring calves 85 percent of the herds fell in four groups which showed a cost range of from $70 to $150. In the case of the fall calves 76 percent of the herds fell in three groups which showed a cost range of from $70 to $130.

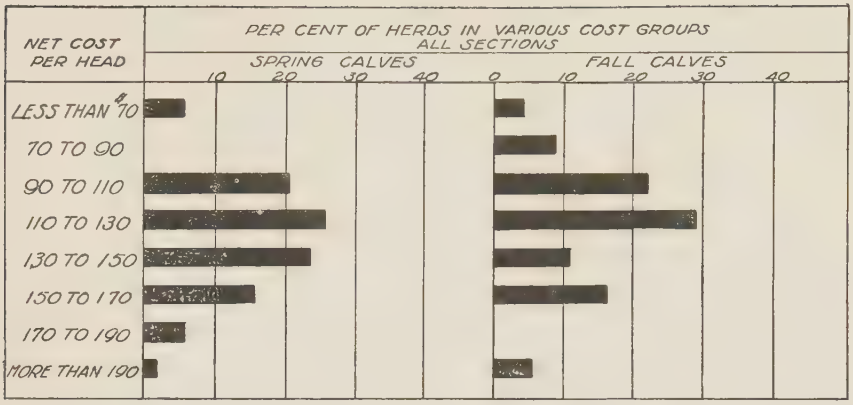


Figure 3.—Range and Distribution of Net Costs per Head till Time of Freshening for Purebred Herds

Figure 3 shows that the net cost per head till time of freshening for purebred spring and fall calves varied from approximately $70 to $240. In the case of the spring calves 84 percent of the herds fell in four groups which showed a cost range of from $90 to $170. In the case of the fall calves 79 percent of the herds fell in four groups which showed a cost range of from $90 to $170.

The very low-cost herds shown in Figures 1, 2, and 3 were the results of "roughing" the heifers through the winter and of inadequate whole-milk feeding. The unusually high-cost herds were in most cases due mainly to wasteful feeding methods, especially during the first six months. However, the costs of most herds fell in rather narrow limits, as indicated in Table 1. These costs show the variations which occurred among feeders of reasonable efficiency.

Table 1.—Range and Distribution of Net Costs Per Head for Grade and Native Herds and Purebred Herds until Time of Freshening

Net Cost per Head	Spring Calves		Fall Calves	
	Grade and Native (No. of Herds)	Purebred (No. of Herds)	Grade and Native (No. of Herds)	Purebred (No. of Herds)
$50 to $70	4	3	6	2
$70 to $90	10	9	21	4
$90 to $110	26	9	28	10
$110 to $130	25	11	15	13
$130 to $150	10	10	7	5
$150 to $170	5	7	6	7
$170 to $190	2	3	1	0
$190 to $210	1	1	0	3

Many dairymen were able to raise heifers for less than the above estimates by using unpaid family labor and feeding some unmarketable feeds. The estimates have been figured on the basis of paying the prevailing wages for labor and the market prices for all feeds.

Distribution of Total Cost over Successive Seasons

In selling or buying heifers during the period of their growth it is valuable to know what part of the total cost of raising has been expended at the age of the animal under consideration. Tables 2, 3, 4, and 5 state the percentage of the total average feed and labor costs expended during successive seasons and years. Only feed and labor costs are given in the tables because these costs constituted 90 percent of the total cost of raising and, therefore, give a good approximation of seasonal and yearly costs.

Table 2.—Percentage of the Total Average Feed and Labor Costs Expended on Spring Calves during Successive Seasons and Years for 53 Grade and Native Herds

Costs	First Year			Second Year			Total for Two Years (Percent)
	First Pasture Season (Percent)	First Feeding Season (Percent)	Total (Percent)	Second Pasture Season (Percent)	Second Feeding Season (Percent)	Total (Percent)	
Feed	35.7	21.9	57.6	7.8	34.6	42.4	100.0
Labor	33.5	33.2	66.7	2.0	31.3	33.3	100.0

Table 3.—Percentage of the Total Average Feed and Labor Costs Expended on Fall Calves during Successive Seasons and Years for 53 Grade and Native Herds

Costs	First Year			Second Year			Total for Two Years (Percent)
	First Feeding Season (Percent)	First Pasture Season (Percent)	Total (Percent)	Second Feeding Season (Percent)	Second Pasture Season (Percent)	Total (Percent)	
Feed	46.7	6.3	53.0	35.5	11.5	47.0	100.0
Labor	57.0	2.0	59.0	39.1	1.9	41.0	100.0

Table 4.—Percentage of the Total Average Feed and Labor Costs Expended on Spring Calves during Successive Seasons and Years for 44 Purebred Herds

Costs	First Year			Second Year			Total for Two Years (Percent)
	First Pasture Season (Percent)	First Feeding Season (Percent)	Total (Percent)	Second Pasture Season (Percent)	Second Feeding Season (Percent)	Total (Percent)	
Feed	42.3	20.1	62.4	6.6	31.0	37.6	100.0
Labor	31.5	32.6	64.1	3.6	32.3	35.9	100.0

Table 5.—Percentage of the Total Average Feed and Labor Costs Expended on Fall Calves during Successive Seasons and Years for 44 Purebred Herds

Costs	First Year			Second Year			Total for Two Years (Percent)
	First Feeding Season (Percent)	First Pasture Season (Percent)	Total (Percent)	Second Feeding Season (Percent)	Second Pasture Season (Percent)	Total (Percent)	
Feed	53.5	5.9	59.4	31.0	9.6	40.6	100.00
Labor	53.0	4.2	57.2	38.6	4.2	42.8	100.00

The expenditure for feed during the first year ranged from one-half to three-fifths of the total cost of feed for the first two years. Furthermore, the greater part of this expenditure for the first year occurred during the first six months. For fall calves the expenditure for feed during these six months was approximately half of the total expenditure for the two years. For spring calves this expenditure ranged from one-third to two-fifths of the total feed cost. Figure 4 shows the expenditure for feed graphically. Tables 6 and 7 give these costs numerically.

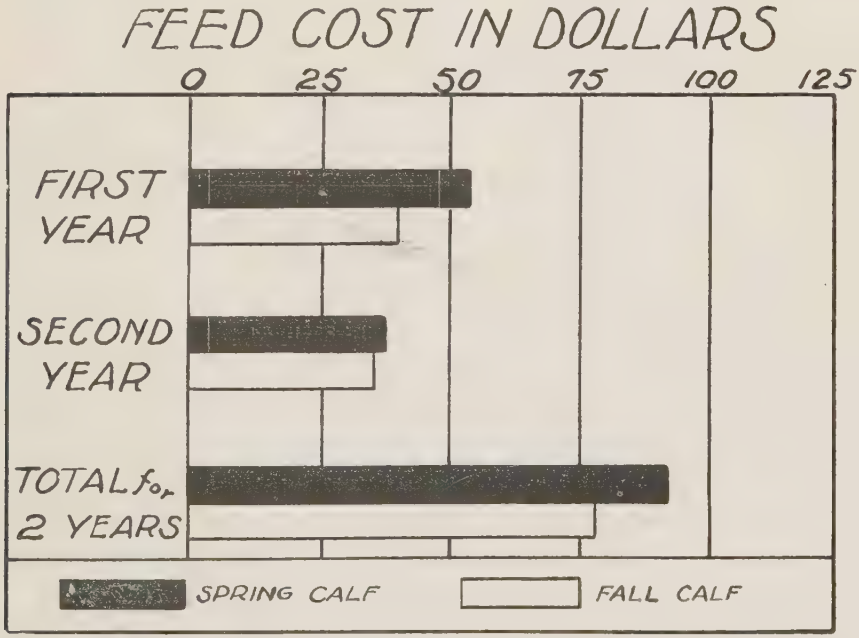


Figure 4.—Difference in Average Feed Costs by Years for Grade and Native Heifers

Figure 4 illustrates the difference in the average feed costs by years for grade and native heifers. From one-half to three-fifths of the total feed cost occurred during the first year.

About three-fifths of the labor costs for the two years occurred during the first year for both fall and spring calves. During the first six months of the first year about one-third of the total labor costs was expended for spring calves and more than one-half was expended for fall calves.

Table 6.—Average Feed Costs per Head for Grade and Native Spring Calves by Seasons and Years

Sections	First Year				Second Year				Total for Two Years
	No. of Herds	First Pasture Season	First Feeding Season	Total	No. of Herds	Second Pasture Season	Second Feeding Season	Total	
All sections	53	$33.32	$20.52	$53.84	53	$ 7.31	$32.24	$39.55	$93.39
Large city fluid milk sections	22	30.72	22.59	53.31	22	7.13	32.77	39.90	93.21
Small city milk and cream sections	20	39.14	20.09	59.23	20	6.76	34.28	41.04	100.27
Creamery section	11	27.93	17.17	45.10	11	8.70	27.45	36.15	81.25

Table 7.—Average Feed Costs per Head for Grade and Native Fall Calves by Seasons and Years

Sections	First Year				Second Year				Total for Two Years
	No. of Herds	First Feeding Season	First Pasture Season	Total	No. of Herds	Second Feeding Season	Second Pasture Season	Total	
All sections	53	$37.19	$5.07	$42.26	53	$28.21	$ 9.16	$37.37	$79.63
Large city fluid milk sections	22	35.19	5.00	40.19	22	30.34	8.16	38.50	78.69
Small city milk and cream sections	20	41.84	4.68	46.52	20	28.30	9.13	37.43	83.95
Creamery section	11	32.72	5.92	38.64	11	21.92	10.64	32.56	71.20

Division of Total Cost into Various Items

Feed was the most important item of cost. For all classes of heifers approximately 77 percent of the cost was for feed alone. Labor was the item next in order of importance, ranging from 11 percent to 14 percent of the total cost. Interest costs were next in order of amount but equalled only about 3 percent for grade and native and 6 percent for purebred heifers. Housing costs ranged from about 2½ to 3 percent. All other costs combined equalled approximately 3 percent of the total cost.

The only marked difference to be found in the costs of raising the three classes of heifers shown in Table 8 is the smaller percentage expended for labor and the larger percentage for interest in the case

Table 8.—Percentage of Total Cost of Raising Three Classes of Heifers Attributed to Various Cost Items

Costs	For Grade and Native Heifers Until Two Years of Age (Percent)	For Grade and Native Heifers Until Time of Freshening (Percent)	For Purebred Heifers Until Time of Freshening (Percent)
Gross Cost	100.0	100.0	100.0
Feed	77.9	76.8	77.3
Labor	13.1	14.1	11.2
Housing	2.9	2.8	2.6
Bedding	1.3	1.5	1.4
Interest	3.1	3.1	5.9
Loss from death	1.1	1.1	1.1
Miscellaneous	0.6	0.6	0.5

of purebred heifers. Purebreds usually received more and better feed, which made the labor item smaller in proportion to the total cost. The labor costs, however, usually were greater in amount than were the costs for grade and native heifers. The greater value of purebred heifers raised the charges for interest.

Differences in Costs between Typical Dairy Sections

The three types of sections compared in this analysis comprise an important dairy section in each of ten counties. Ohio, Wood, Marion, and Harrison counties contain the "large city fluid milk sections" shown in the figure on the cover page; Marshall, Tyler, Pleasants, Lewis, and Upshur counties the "small city milk and cream sections;" and Greenbrier county the "creamery section."

The creamery section showed the lowest costs of raising grade and native heifers for the summer of 1925 and winter of 1926. The large city fluid milk sections were next in order, while the small city milk and cream sections had the highest costs. The differences in the average costs in these types of sections is appreciable, being from $7 to $16 per head.

A study of Table 9 shows that most of the differences in costs between the sections are due to differences in feed costs.

The creamery section showed cheaper feed costs because of a lower price for milk and because the heifers could be pastured more months during the year. The differences in the costs of hay were very small between the sections.

High costs for feed in the small city milk and cream sections were due almost entirely to uneconomical feeding methods during the first year. More experience with dairy cattle in these sections no doubt

Table 9.—Average Costs of Raising Grade and Native Heifers to Two Years of Age in Typical Dairy Sections of West Virginia

Costs	Small City Milk and Cream Sections	Large City Fluid Milk Sections	Creamery Section
Feed	$92.11	$87.95	$76.22
Labor	15.83	13.80	13.64
Housing	2.71	3.70	2.89
Bedding	1.05	1.69	2.33
Interest	3.44	3.51	3.16
Loss from death	1.27	1.27	1.27
Miscellaneous	.65	.69	.91
Gross cost	117.06	110.61	100.42
Manure credits	11.06	11.60	10.37
Net cost	106.00	99.01	90.05

will bring the costs down to a level or even lower than the costs in the large city fluid milk sections because hay, pasture, and labor were slightly cheaper in the small city milk and cream sections. The labor costs per head for the latter sections were also the highest for all sections since there were fewer heifers per herd.

The costs of purebreds showed very slight differences between the small city milk and cream sections and the large city fluid milk sections. In the creamery section very few purebred herds were visited.

One should not conclude that raising dairy heifers should be expanded in the low-cost sections and curtailed in the high-cost sections. Low costs are but one indication and not conclusive proof that this would be a wise course either for certain sections or for particular dairymen. Raising dairy heifers may yield a profit, but alternative enterprises may pay better. On the other hand, the high cost sections may have no alternative enterprise which pays a better profit. Nevertheless when purchasing heifers or cows one will normally be able to find more raised and to buy them cheaper in sections where heifers are raised at lower costs.

Difference in Costs between Spring and Fall Calves

It costs more to raise heifers born in the spring than heifers born in the fall. The difference in the average net cost to two years of age was 12.9 percent more for spring calves than for fall calves. The average net cost until time of freshening was 7.6 percent more for spring calves than for fall calves. The reason for the difference lies in the greater opportunity which fall calves have to take advantage

of cheap pasture feed, as well as in the younger age and smaller size of stock when it enters the winter feeding periods. Table 10 gives the average net costs of raising grade and native heifers for those born in the spring and for those born in the fall.

Table 10.—Average Net Costs of Raising Grade and Native Heifers

Time of Birth	To Two Years of Age	Until Time of Freshening
Spring	$106.03	$112.06
Fall	93.90	104.16

Purebred heifers show a smaller difference in average net costs for spring calves than do grade and native heifers. Purebred spring calves cost 4.3 percent more than fall calves.

Difference in Costs between Purebred and Grade and Native Heifers

The forty-four purebred breeders spent more per head in raising heifers than did the eighty-four breeders of grade and native heifers. This difference is shown in the range in costs which are given in Figures 1, 2, and 3 and in Table 1. Eighty-four percent of the purebred herds had a range in costs of from $90 to $170 for spring calves, while 85 percent of the grade and native herds had a range in costs of from $70 to $150 for spring calves. Thus, when the extremely high and low-cost herds were excluded, the approximate difference in cost was $20 more for purebred than for grade and native heifers. However, the difference in the average net costs was approximately $40 because of a number of purebred herds with extremely high costs.

The reason why more was expended on purebred heifers than on grade and native heifers was not that they required more feed and care to attain the same degree of growth and condition, but that the additional feed and care given purebred heifers made extra good growth and fine condition possible. Buyers of purebred cattle are willing to pay for this increased size and good condition.

Factors Affecting Replacements for the Dairy Herd

No general rule will avail for dairymen in deciding to raise or purchase replacements for the dairy herd. There are several factors which ordinarily must be considered for a particular time and place in making a decision.

The danger of bringing disease to the dairy herd is ever present unless guarded against with extreme care. The added cost of raising a heifer above the cost at which one may be bought is often well spent in order to avoid the danger of contagious abortion or other infectious diseases.

Unless the dairyman buys from tested herds and reliable breeders, there is often the greater danger of buying poor producers. However, a premium usually must be paid for stock of proved production. If cows are purchased from untested herds a buyer must always guard himself against purchasing animals which are offered for sale because of some defects as producers. Of course, in raising heifers there are always some heifers which must be discarded for one reason or another. Both methods, therefore, present hazards. These two classes of risks must be appraised in choosing which course to follow. Individual dairymen can determine from experience whether they are more efficient in avoiding one of these hazards than in avoiding the other.

Of prime importance, of course, is the relative cost of the two methods available for replacement. What it costs a dairyman to raise a cow and for what price he can buy one at a particular time are often the deciding factors in this matter. The cost of raising a cow depends upon the prices of feed, labor, and other cost items and also upon the dairyman's efficiency. On the other hand, heifers can often be raised at a low cost on pasture, feed, and labor which would otherwise go to waste.

Labor often costs very little or nothing if there are children old enough to care for the calves, or if the regular work about the dairy and farm does not occupy the full time of the dairyman. There is often a surplus of pasture, and at certain periods a surplus of milk either as whole milk or as skim milk. Barn room which would otherwise be vacant can be used for the heifers. Any or all of the above advantages may at times reduce very greatly the cost of raising heifers.

The prices which must be paid vary from time to time in response to the number available for sale and the demand. These prices may be less or more than the cost of raising. Costs of raising heifers act merely as a check upon the supply.

It may be possible during certain periods to buy heifers and cows in other dairy sections of the state or outside the state for less than the cost of raising. Dairy sections with low feed-costs usually sell at the lowest prices. Furthermore, better stock may often be obtained in this way.

A comparison of prices to be paid and the cost of raising cannot be the deciding factors in all cases. The risks of diseases and the lack of knowledge as to breeding and production must be considered when buying for replacements.

Bulletin 225 November, 1929

The Relative Value of High-Grade and Low-Grade Calves

Marketed as Two-year-old Steers

by E. A. LIVESAY

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

FIGURE 3.—Representative carcass produced from the good to choice lot of calves on the right and from the common lot of calves on the left. Note the fuller and smoother appearance of round, loin, rib, and chuck of the carcass on the right. (See, also, Figure 4 on page 10.)

*The Relative Value of High-Grade and Low-Grade Calves Marketed as Two-Year-Old Steers**

by E. A. LIVESAY

IN ORDER to gain additional information in regard to the relative values of well-bred beef calves as compared to calves of nondescript breeding, the state Agricultural Experiment Station started a feeding trial with such calves in the fall of 1922. Twenty-four steer calves were purchased in Harrison County in October, 1922. Twelve of these were high-grade calves of Hereford breeding, graded as good to choice, while twelve were low-grade calves of nondescript breeding, ten of which were graded as common and two as medium. The calves were started on the trial on November 17, 1922, and were marketed from grass on September 18, 1924; thus the calves were carried through two winter feeding periods and two summer grazing periods.

As the calves were to be carried over two winters and two summers it was thought advisable to divide each grade into two lots of six calves and make a test of the value of cottonseed meal as against linseed oilmeal in the ration for calves and yearlings.

Division, Stabling, and Feeding of Calves

The high-grade calves were of Hereford breeding. From all appearances they would have passed for purebred calves. They were fairly uniform in conformation and thick enough to be graded as good to choice beef calves. *(See Figure 1.)* The low grade calves were less uniform in conformation and with the exception of two calves they lacked thickness, were leggy, off color, and graded as common. Two calves were thicker and appeared to be fairly well-bred; one would have passed for a Shorthorn, while the other would have been considered a cross between the Aberdeen-Angus and Hereford breeds. The ten common calves appeared to represent about all the beef and dairy breeds in color and conformation. These calves were approximately the same age as the high-grade calves. *(See Figure 2.)*

*Submitted for publication September, 1927.

FIGURE 1.—The twelve high-grade calves which were graded as good to choice at the start of the experiment

In order to test the value of linseed oilmeal and cottonseed meal in rations for calves and yearlings the good to choice and the common calves were divided into two lots of six each. One lot of good to choice and one lot of common calves received linseed oilmeal in their rations while the other lots (one good to choice and one common) received a similar amount of cottonseed meal. Rations were composed of the same feeds and proportions for all lots except for the linseed oilmeal and cottonseed meal and were fed at the same rate per 1,000 pounds live weight. The lots of calves receiving linseed oilmeal and cottonseed meal also received these feeds in their rations as yearling steers. During the winters of 1922-23 and 1923-24 the calves and yearlings were fed twice daily. All lots were kept in pens in the barn at night and turned out in small lots during the day. Salt was kept in small boxes in all pens continuously, and all calves had equal access to water in the lots during the day. All feeds were fed in racks and troughs in the barn.

Feeds and Character of Pasture

The corn silage was made from Boone County white corn (ears included) in a good mature silage stage when ensiled. The mixed hay was composed of clover and timothy grown on the animal husbandry farm of the Experiment Station. All other feeds were bought.

The feeds were all of good quality during the winter feeding period of 1922-23. All were of good quality in 1923-24 with the exception of the mixed hay. The hay was damaged in the field by heavy rains in the summer of 1923, but the yearling steers seemed to relish it.

Table 1 gives the chemical analyses of the feeds fed as well as the analyses of similar feeds given by Henry and Morrison.* The

**Feeds and Feeding*, 18th ed. (1922).

TABLE 1.—Analyses of Feeds Fed Compared to Analyses of Similar Feeds Given by Henry and Morrison

Feed	Water	Ash	Crude Protein	Carbohydrates		Fat
				Fiber	N-free Extract	
1922-23						
Corn silage	76.53	1.57	2.24	5.54	13.53	0.59
Mixed hay	5.64	4.03	6.45	32.25	49.23	2.40
Cottonseed meal	6.67	6.00	32.84	9.69	37.05	7.75
Linseed oilmeal	7.06	5.18	31.47	14.18	35.50	6.61
Shelled corn	9.90	1.14	8.69	2.17	73.94	4.16
1923-24						
Corn silage	69.18	1.21	1.99	6.98	19.74	0.90
Mixed hay	5.26	4.02	7.00	34.86	46.62	2.24
Cottonseed meal	7.07	6.18	36.73	12.67	31.30	6.05
Linseed oilmeal	8.01	5.58	31.87	8.00	40.25	6.29

Henry and Morrison (Feeds and Feeding)

Feed	Water	Ash	Crude Protein	Carbohydrates		Fat
				Fiber	N-free Extract	
Corn silage, well matured	73.7	1.7	2.1	6.3	15.4	0.8
Mixed hay, grade No. 1 (clover and timothy)	12.2	6.1	8.6	29.9	40.8	2.4
Cottonseed meal, good	7.9	6.4	37.6	11.5	28.4	8.2
Linseed oilmeal (old process)	9.1	5.4	33.9	8.4	35.7	7.5
Shelled corn, dent	12.0	1.5	9.9	2.0	69.7	4.9

FIGURE 2.—The twelve calves of nondescript breeding, ten of which were graded as common and two as medium at the start of the experiment

mixed hay was low in ash and crude protein each year, compared to the average given by these authors.

Table 2 gives the digestible nutrients of the feeds fed during the two winters. The nutritive ratios of rations given in Tables 3 and 5 are based upon the digestible nutrients as given in Table 2.

TABLE 2.—Digestible Nutrients of Feeds Fed

Feed	Digestible Nutrients per One Hundred Pounds				
	1922-23				
	Dry Matter *Pounds*	Crude Protein *Pounds*	Carbohydrate *Pounds*	Fat *Pounds*	Total *Pounds*
Corn silage	23.47	1.14	13.21	0.48	15.43
Mixed hay	94.36	3.03	45.98	1.08	51.44
Cottonseed meal	93.33	27.59	31.37	7.36	75.52
Linseed oilmeal	94.94	28.01	35.77	5.88	77.01
Shelled corn	90.10	6.43	70.74	3.87	85.87
	1923-24				
Corn silage	30.82	0.97	18.55	0.74	21.18
Mixed hay	94.74	3.36	46.33	1.12	52.21
Cottonseed meal	92.93	30.85	28.16	5.75	71.95
Linseed oilmeal	91.99	28.36	35.95	5.60	76.91

The same pasture was used for each year. It was considered a poor pasture for fattening. Very few acres of the area were classed as a fair sod. The majority of the acreage contained small brush and an inferior sod. The grasses, where the sod was considered fair, consisted of bluegrass and white clover. The grasses of the remainder of the pasture consisted mainly of "poverty grass" *(Danthonia spicata)* and various weeds.

Table 3 includes the data of the first winter feeding period. All lots were fed the same amounts of feeds in their rations per 1,000 pounds live weight. Rations for Lots I (good to choice) and II (common) contained cottonseed meal, while those for Lots III (good to choice) and IV (common) contained the same amount of linseed oilmeal. The variations in the rations are due to two causes: viz., variation in the lot weights, and the amounts of roughages which were weighed back from time to time. The amount of the feed (mixtures) per lot was increased each twenty-eight days according to the gains of the respective lots. The calves were fed during the first eighty-

seven days on a ration composed of the following feeds and amounts per 1,000 pounds live weight: corn silage, 40 pounds; mixed hay, 10 pounds; cottonseed meal, 4 pounds (Lots I and II); linseed oilmeal, 4 pounds (Lots III and IV); cracked corn, 3 pounds.

The calves of Lots I and II failed to clean up the roughage of this ration during the first half of February. At the close of the 87-day period, February 13, the ration was reduced to the following amounts per 1,000 pounds live weight: corn silage, 38 pounds; mixed hay, 4 pounds; cottonseed meal, 4 pounds (Lots I and II); linseed oilmeal, 4 pounds (Lots III and IV); cracked corn, 1 pound. This rate of feeding was continued until the end of the period, or sixty-seven days.

TABLE 3.—Results of Winter Feeding in 1922-23 (November 17 to April 20 inclusive—154 days)

Items	Grade of Steers			
	Lot I	Lot II	Lot III	Lot IV
	Good to Choice	Common	Good to Choice	Common
Number of steers per lot	6	6	6	6
Average initial weight (pounds)	447	313	457	321
Average final weight (pounds)	611	479	636	497
Average gain (pounds)	164	166	179	176
AVERAGE RATION PER STEER (pounds)				
Corn silage	18.43	14.42	19.86	14.52
Mixed hay	2.78	2.45	3.00	2.49
Cracked corn	0.85	0.64	0.90	0.65
Cottonseed meal	2.01	1.53	....	....
Linseed oilmeal	....	....	2.13	1.55
Nutritive ratio	1:6.22	1:6.25	1:6.31	1:6.27
TOTAL FEED CONSUMED (pounds)				
Corn silage	17,032	13,324	18,355	13,414
Mixed hay	2,564	2,267	2,802	2,297
Cracked corn	787	595	836	604
Cottonseed meal	1,861	1,411	....	....
Linseed oilmeal	....	....	1,966	1,429
COST OF FEEDS				
Corn silage @ $6 per ton	$51.09	$39.98	$55.06	$40.24
Mixed hay @ $18 per ton	23.07	20.41	25.21	20.67
Cracked corn @ 84c per bushel	11.80	8.92	12.54	9.05
Cottonseed meal @ $50 per ton	46.52	35.26	....	....
Linseed oilmeal @ $50 per ton	....	....	49.14	35.72
Total cost of wintering	$132.48	$104.57	$141.95	$105.68
Cost of wintering per steer	22.08	17.43	23.66	17.61

Comparative Value of Linseed and Cottonseed Meal

The linseed oilmeal (Lots III and IV) gave slightly more gain for the 154 days and the calves in these lots seemed to have a more uniform appetite than those of Lots I and II, which received cottonseed meal.

Table 4 gives the gains on each lot for the first grazing season of 236 days.

TABLE 4.—Summer Gains in 1923 (April 21 to December 12 inclusive—236 days)

Items	Average Weight per Steer			
	Lot I *Pounds*	Lot II *Pounds*	Lot III *Pounds*	Lot IV *Pounds*
Average initial weight	611	479	636	497
Average final weight	769	663	747	678
Average gain	158	184	111	181

Table 5 gives the data for the second wintering period. The yearlings were fed and handled much the same as in the previous winter when they were calves. The rations for the entire period of the second year remained constant and were composed of the following feeds and amounts per 1,000 pounds live weight: corn silage, 35 pounds; mixed hay, 4 pounds; cottonseed meal, 1½ pounds (Lots I and II); linseed oilmeal, 1½ pounds (Lots III and IV).

The amount of feed each lot received was increased each twenty-eight days according to gains made. The cottonseed meal and linseed oilmeal lots did not reflect the difference in appetite as evidenced in the previous winter. Gains were slightly in favor of cottonseed meal. The cottonseed meal was more than 3 percent higher in digestible crude protein than the previous year,—a partial explanation of the greater gain for the cottonseed lots.

Table 6 gives the gains for the second grazing season. All lots were shipped to market following the final weigh period on September 18, and were sold on the Pittsburgh market on September 22, 1924.

Table 7 is a summation of the summer and winter gains for the two winter feeding periods and the two grazing periods. This table shows that the good to choice calves made slightly more winter gains for the two years, while the common calves made greater summer gains and also greater gains for the combined winter and summer

TABLE 5.—Results of Winter Feeding in 1923-24 (December 13 to May 1 inclusive—140 days)

Items	Grade of Steers			
	Lot I	Lot II	Lot III	Lot IV
	Good to Choice	Common	Good to Choice	Common
Number of steers per lot	6	6	6	6
Average initial weight (pounds)	769	663	747	678
Average final weight (pounds)	898	771	862	878
Average gain (pounds)	129	108	115	100
AVERAGE RATION PER STEER (pounds)				
Corn silage	28.45	24.51	27.79	24.69
Mixed hay	3.25	2.81	3.16	2.82
Cottonseed meal	1.21	1.04	....	....
Linseed oilmeal	....	....	1.19	1.05
Nutritive ratio	1:10.33	1:10.34	1:10.69	1:10.71
TOTAL FEED CONSUMED (pounds)				
Corn silage	23,905	20,591	23,343	20,749
Mixed hay	2,736	2,359	2,656	2,374
Cottonseed meal	1,018	880	....	....
Linseed oilmeal	....	....	1,002	888
COST OF FEEDS (value of feeds the same as in Table 3)				
Corn silage	$71.71	$61.77	$70.03	$62.24
Mixed hay	24.62	21.23	23.90	21.36
Cottonseed meal	25.46	22.00	....	....
Linseed oilmeal	....	....	25.05	22.12
Total cost of wintering	$121.79	$105.00	$118.98	$105.72
Cost of wintering per steer	20.30	17.50	19.83	17.62

periods for the two years, or the duration of the experiment.

Table 8 includes the combined data on the two lots of good to choice and the two lots of common calves. It covers the costs of the winter feeds and pasture for two years and gives the actual sale values on the Pittsburgh market as well as the relative value of the

TABLE 6.—Summer Gains in 1924 (May 1 to September 18 inclusive—140 days)

Items	Average Weight per Steer			
	Lot I *Pounds*	Lot II *Pounds*	Lot III *Pounds*	Lot IV *Pounds*
Average initial weight	898	771	862	778
Average final weight	1113	1028	1115	1072
Average gain	215	257	253	294

FIGURE 4.—A different view of the same side of carcasses as shown in Figure 3 (page 2). This view brings out the striking difference in the thickness of the carcasses

calves at the beginning of the experiment. It should be kept in mind that these cattle were marketed on one of the lowest markets (Pittsburgh) since the war,—a market crowded with cattle of the quality and finish of the twelve steers classed as good to choice when entering the experiment as calves. The salesman for the commission company handling these cattle was positive that he could have sold the higher-grade cattle for $1.00 per 100 pounds more money had they been on the market a week earlier. He also was equally positive that the lower-grade cattle could not have been sold for a higher figure on the earlier market, as it was the small numbers of low-grade cattle on the market that allowed them to sell as close to the better grade as they did. The market conditions which existed when these cattle were sold give a decided advantage to the common calves. Table 8 gives the relative value of good to choice as against common calves.

Carcasses

The data in Table 8 show that the steers developed from the good to choice calves dressed approximately 3 percent more than steers developed from the common calves. This table also shows that the hides of the higher-grade steers weighed approximately ten pounds more each than the hides of the lower grade. The carcasses from the higher grade of steers were thicker from every standpoint, and the fat was of a more desirable color. A side of a representative carcass from each lot is shown in Figures 3 and 4 with footnotes pointing out the differences.

TABLE 7.—Summary of Winter and Summer Gains of Good to Choice and Common Steers

Items	Grade of Steers			
	Lot I	Lot II	Lot III	Lot IV
	Good to Choice *Pounds*	Common *Pounds*	Good to Choice *Pounds*	Common *Pounds*
Average winter gain 1922-23	164	166	179	176
Average winter gain 1923-24	129	108	115	100
Average total winter gain	293	274	294	276
Average summer gain 1923	158	184	111	181
Average summer gain 1924	215	257	253	294
Average total summer gain	373	441	364	475
Average total gain winter and summer	666	715	658	751

TABLE 8.—Summary Showing Relative Value of Good to Choice as Against Common Calves

Items	Good to Choice Calves	Common Calves
Number of steers	12	12
Average home weight (pounds)	1,114	1,050
Average Pittsburgh weight or market weight (pounds)	1,068	1,008
Average drift (pounds)	46	42
Average dressed weight (warm) (pounds)	602	542
Average dressed percent (warm weight)	56.4	53.8
Average hide weight (pounds)	81.4	71.7
Cost of feeds and pasture:		
Total cost of winter feeds per steer	$42.84	$35.08
Total cost of pasture per steer	17.00	17.00
Total cost of feed and pasture per steer	$59.84	$52.08
Selling price on market (per 100 pounds)	8.00	6.55*
Sale value per steer	85.44	66.08
Difference between sale value and cost of production, or relative value of calves at start of experiment	25.50	14.00

*Average selling price. Ten steers sold for $6.75 and two steers sold for $5.50 per 100 pounds.

SUMMARY

There was practically no difference between the winter gains made by the good to choice and the common calves during the first winter (1922-23). Greater gain was made by calves of both lots (III and IV) which received linseed oilmeal as compared to Lots I and II, which received cottonseed meal. The common calves, regardless of the difference in their winter rations, made larger summer gains than did the good to choice calves for the first grazing season (1923). This greater summer gain can be explained on the basis of the conditon of the calves. The common calves entered the winter feeding period in a thinner condition and made about the same winter gains as did the good to choice lots. They were judged to be thinner in condition when the grazing period began and a greater gain on grass was expected.

The good to choice calves made slightly larger gains the second winter (1923-24) as yearling steers than did the common calves. A slight advantage also was noted in favor of the cottonseed meal lots during the second winter. The gains on grass the second summer were the reverse of winter gains in all lots. The lot making the greater winter gain made the smallest gain on grass. This corresponds with gains made during the winter and the following grazing season at this station, when the steers are one year older.

The market at the time these steers were sold gave a relative value of $25.50 for the good to choice calves and $14.00 for the common calves. As mentioned in connection with the data in Table 8, the condition of the market was in favor of the lower grade of steers. Thus the common calves had a value of only three-fifths the value of the good to choice calves.

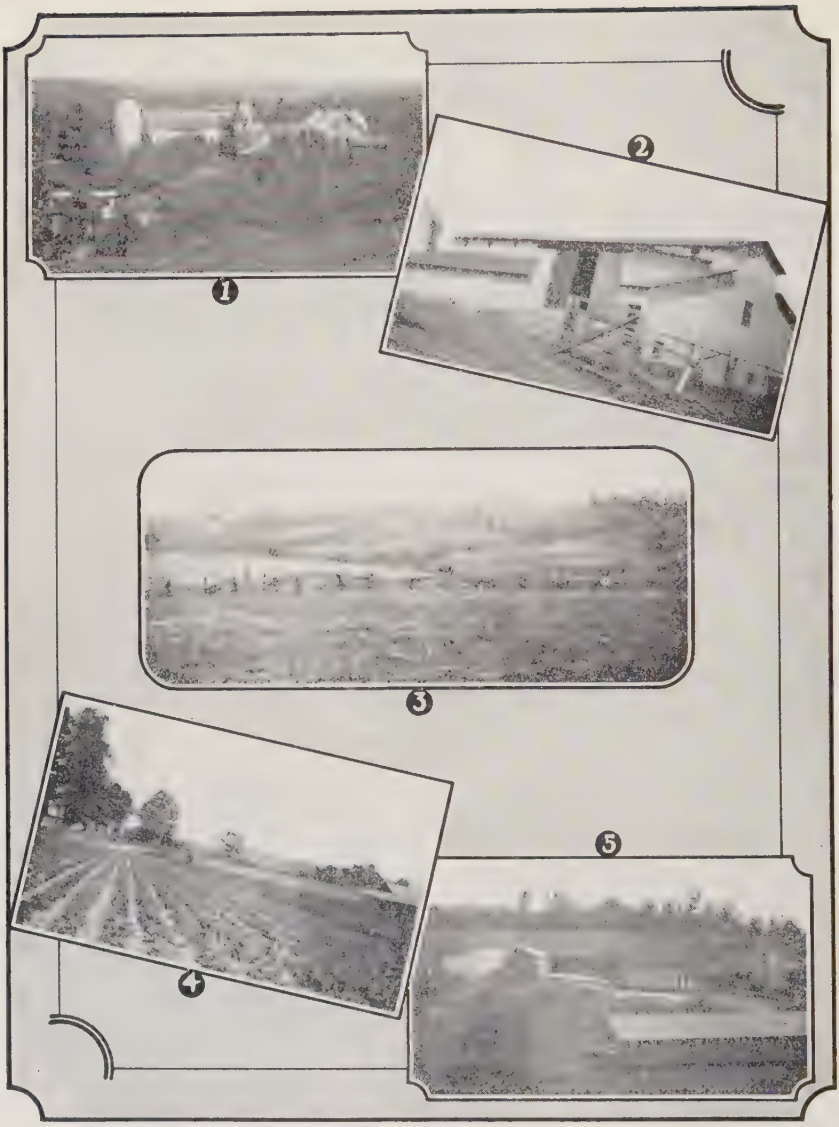
The good to choice calves developed into steers with a higher dressing percentage. The carcasses were smoother and thicker and carried a more desirable coloring of fat.

Bulletin 226 January, 1930

Adjusting Agricultural Production and Distribution in the Beckley Area to Meet Home Market Demands

by W. W. ARMENTROUT

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN



1. Bird's-eye view of Raleigh Dairy Company farm at Daniels, W. Va.
2. New fire-proof dairy barn of the Raleigh Dairy Company.
3. A typical farming section in Raleigh County, well adapted to dairying and trucking.
4. Poultry and truck farm owned by C. D. Pittman, Glen White, W. Va. A profitable business particularly in this section.
5. Poultry farm and hatchery of N. L. Sonders, Beckley, W. Va.

*Adjusting Agricultural Production and Distribution to Meet Home Market Demands in the Beckley Area**

by W. W. ARMENTROUT

THE PRESENT report of a study of the Beckley area is the third of a series of reports dealing with the consumption of food commodities in West Virginia cities and with the production of these commodities in adjacent farming territory.

Studies have been made of the Charleston and Clarksburg areas, reports of which have been published as West Virginia Agricultural Experiment Station Bulletins 188 and 212, respectively.[1]

Beckley was included in the "Charleston Trade Area" in the study made of that area in 1924. It was selected for the present study as a town representative of conditions in the smaller towns of the southern West Virginia coal fields.

Beckley, a town of 4,149,[2] is the county seat of Raleigh County. It is the center of the business activities of the Winding Gulf coal region, as well as the trading center for the people in a number of mining towns of that section. It is not, however, a distributing center for food products, since company stores in the mining towns and hucksters provide this service.

The population of Raleigh County increased 341 percent during the twenty-year period from 1900 to 1920. This increase was due chiefly to the development of coal mining in the region. The 1920 census shows that in Raleigh County 8,524 persons were employed in mines, 1,518 as farm operators, and 592 in other industries. Some of the number listed as farm operators do little more than make their home on a small farm, deriving their main income from employment in mines nearby. Agriculture has been pushed aside in the march of industry, which now predominates in the area.

---

*Submitted for publication September, 1927.

[1]See also Bulletin 228 of this Station for report of Wheeling study.

[2]*Fourteenth Census of the United States* (1920).

Good agricultural land is scarce in Raleigh County, and for that reason the county cannot now be regarded as a potential agricultural section. But there are small areas of land which can be made productive enough to supply a larger part of the local food demands than is being provided at present.

RAILROADS AND HIGHWAYS

Beckley is located on branch lines of the Chesapeake & Ohio and Virginian Railways. Service is less satisfactory than on the main lines of these roads, and rates are somewhat higher.

Until the fall of 1926 Beckley had but one outlet over a hard-surfaced road, a very mediocre road leading to Charleston. Recently roads have been opened up leading to Hinton and Bluefield, but even yet the better farming sections of Raleigh County are not tapped by improved roads. The road to Hinton opened up a trucking section along the New River in Summers County which promises to supply much of the local demand for seasonal vegetables. In the fall of 1926 a hard-surfaced road was completed which connects Beckley with Bluefield. There is some good farm land in Mercer County, in which Bluefield is located, and there is an excellent farming section in Tazewell County, Virginia, which joins Mercer County. The new road has made this whole region available to consumers in Beckley and other coal towns.

There is need for an early completion of a road from Hinton to Alderson and into Greenbrier and Monroe Counties. Such a road would put the coal fields within easy reach of these good agricultural regions.

Hucksters buy vegetables and produce on the Huntington markets and bring them into Beckley and the Winding Gulf coal fields by motor truck. The amount of commodities brought in by truck was not ascertained, but from reports of retail grocers the impression was gained that perhaps as much as one-half of the vegetables and produce consumed were brought to market in this way. Along with the opening of improved roads, freight receipts showed a decrease.

SOURCES OF DATA

The data on freight shipments were obtained for a twenty-four months' period from station records of the Chesapeake & Ohio and Virginian Railways at their Beckley stations. Records of express receipts for a corresponding period were taken directly from express way-bills in the district accounting offices of the Southeastern Express Company in Washington. Express charges for the various commodi-

ties were not obtained because of the great number of mixed shipments, with only total charges given.

Records of express receipts for the month of November and December, 1926, and January, 1927, were not available because of an experiment in accounting then under trial by the express company.

Data on local production were not obtained.

RECEIPTS OF COMMODITIES

The present study concerns those commodities which were being produced to some extent in the farming sections of the Beckley area.

Potatoes

Table 1 shows the receipts of potatoes on the Beckley market for a two-year period beginning April, 1925, and ending March, 1927, together with carrying charges and origin of shipment. No potatoes were received by express. Large quantities were shipped from wholesale markets, as is evident from shipments made from Hinton, Charleston, Cincinnati, and Columbus.

The receipts of potatoes during the period of April, 1926, to March, 1927, amounted to about 64 percent of the receipts during the previous year. This may be accounted for partially by the recent opening of roads through some of the better agricultural land in neighboring counties, permitting the trucking to market of more locally grown potatoes. Such potatoes, trucked in, have taken the place of many which formerly had been shipped in. There was no indication of decreased consumption.

Considerable expansion in the potato acreage has developed in Summers, a neighboring county, during the past four years, but as indicated by the data in Table 1, there still is room for expansion before the demands of the market are met.

The average carrying charges were about 52c per hundred pounds, but on potatoes shipped from wholesale markets there was an additional first transportation cost not included in this figure.

Tomatoes

Table 2 shows the quantity of tomatoes received in Beckley by freight, the origin of shipment, and the carrying charges for two twelve-months' periods. The receipts for the year of April, 1926, to March, 1927, amounted to only about 8½ percent of the receipts of the previous twelve months. There was an expansion in tomato production in the New River section along with the opening of the road

TABLE 1.—Receipts of Potatoes in Beckley by Freight: State or City from Which Shipped, Quantity, and Carrying Charges by Months, April, 1925, to March, 1927, Inclusive

State or City from Which Shipped	Total				April, 1925		May, 1925		June, 1925		July, 1925	
	Pounds		Carrying Charges		Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
	1925-26	1926-27	1925-26	1926-27								
Total	905675	578896	$4351.25	$3108.03	232680	$1275.65	153180	$765.90	181845	$1013.38	124500	$520.87
Michigan	306000	273000	1611.90	1555.80	156000	819.90	117000	585.00	33000	207.90	------	------
New York	171810	------	859.52	------	37680	188.40	36180	180.90	97950	490.22	------	------
Wisconsin	39000	36240	268.25	255.49	39000	268.25	------	------	------	------	------	------
South Carolina	36075	------	274.17	------	------	------	------	------	36075	274.17	------	------
Virginia	130720	125582	575.27	580.76	------	------	------	------	3920	13.84	82000	346.31
Hinton, W. Va.	74740	35775	186.82	91.77	------	------	------	------	10900	27.25	12200	30.50
Charleston, W. Va.	41810	3450	60.52	11.73	------	------	------	------	------	------	300	1.02
Kentucky	30000	------	143.04	------	------	------	------	------	------	------	30000	143.04
Ohio	37620	------	227.43	------	------	------	------	------	------	------	------	------
Cincinnati	37900	3115	144.33	14.84	------	------	------	------	------	------	------	------
Columbus	------	21209	------	116.09	------	------	------	------	------	------	------	------
Maryland	------	15650	------	93.90	------	------	------	------	------	------	------	------
Indiana	------	36000	------	185.40	------	------	------	------	------	------	------	------
North Carolina	------	28875	------	202.25	------	------	------	------	------	------	------	------

State or City from Which Shipped	August, 1925		September, 1925		October, 1925		November, 1925		December, 1925		January, 1926	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	9530	$24.45	37500	$129.91	67940	$348.31	12280	$53.56	77570	$196.71	3550	$8.88
Michigan	------	------	------	------	------	------	------	------	------	------	------	------
New York	------	------	------	------	------	------	------	------	------	------	------	------
Wisconsin	------	------	------	------	------	------	------	------	------	------	------	------
South Carolina	------	------	------	------	------	------	------	------	------	------	------	------
Virginia	300	1.38	15200	72.95	19520	93.70	9780	47.04	------	------	------	------
Hinton, W. Va.	9230	23.07	20950	52.37	10500	26.25	2200	5.50	510	1.25	3550	8.88
Charleston, W. Va.	------	------	1350	4.59	300	.93	300	1.02	39560	52.96	------	------
Kentucky	------	------	------	------	------	------	------	------	------	------	------	------
Ohio	------	------	------	------	37620	227.43	------	------	------	------	------	------
Cincinnati	------	------	------	------	------	------	------	------	37500	142.50	------	------
Columbus	------	------	------	------	------	------	------	------	------	------	------	------
Maryland	------	------	------	------	------	------	------	------	------	------	------	------
Indiana	------	------	------	------	------	------	------	------	------	------	------	------
North Carolina	------	------	------	------	------	------	------	------	------	------	------	------

State or City from Which Shipped	February, 1926		March, 1926		April, 1926		May, 1926		June, 1926		July, 1926		August, 1926	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	2700	$7.38	2400	$6.25	3510	$11.26	10498	$41.90	9521	$41.63	28840	$113.38	11835	$50.81
Mich.	------	------	------	------	------	------	------	------	------	------	------	------	------	------
N. Y.	------	------	------	------	------	------	------	------	------	------	------	------	------	------
Wis.	------	------	------	------	------	------	------	------	------	------	------	------	------	------
S. Car.	------	------	------	------	------	------	------	------	------	------	------	------	------	------
Va.	------	------	------	------	------	------	------	------	3950	18.81	13350	64.45	4810	23.07
Hinton	2400	6.00	2300	5.75	2210	5.50	4800	12.00	2400	8.40	10810	27.00	3845	9.50
Charleston	------	------	------	------	------	------	600	2.04	1350	4.59	------	------	------	------
Ky.	------	------	------	------	------	------	------	------	------	------	------	------	------	------
Ohio	------	------	------	------	------	------	------	------	------	------	------	------	------	------
Cincinnati	300	1.38	100	.45	700	3.00	615	3.56	------	------	1800	8.28	------	------
Columbus	------	------	------	------	600	2.76	4483	24.30	1821	9.83	2830	13.65	3180	18.24
Md.	------	------	------	------	------	------	------	------	------	------	------	------	------	------
Ind.	------	------	------	------	------	------	------	------	------	------	------	------	------	------
N. Car.	------	------	------	------	------	------	------	------	------	------	------	------	------	------

State or City from Which Shipped	September, 1926		October, 1926		November, 1926		December, 1926		January, 1927		February, 1927		March, 1927	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	50280	$204.35	47412	$222.58	27235	$129.28	90650	$501.60	67875	$424.25	117000	$666.90	114240	$700.09
Mich.	------	------	------	------	------	------	39000	222.30	39000	222.00	117000	666.90	78000	444.60
N. Y.	------	------	------	------	------	------	------	------	------	------	------	------	------	------
Wis.	------	------	------	------	------	------	------	------	------	------	------	------	36240	255.49
S. Car.	------	------	------	------	------	------	------	------	------	------	------	------	------	------
Va.	40960	170.74	40942	200.57	21570	103.12	------	------	------	------	------	------	------	------
Hinton	6140	15.37	4670	11.75	900	2.25	------	------	------	------	------	------	------	------
Charleston	------	------	------	------	1500	5.10	------	------	------	------	------	------	------	------
Ky.	------	------	------	------	------	------	------	------	------	------	------	------	------	------
Ohio	------	------	------	------	------	------	------	------	------	------	------	------	------	------
Cincinnati	------	------	------	------	------	------	------	------	------	------	------	------	------	------
Columbus	3180	18.24	1800	10.26	3265	18.81	------	------	------	------	------	------	------	------
Md.	------	------	------	------	------	------	15650	93.90	------	------	------	------	------	------
Ind.	------	------	------	------	------	------	36000	185.40	------	------	------	------	------	------
N. Car.	------	------	------	------	------	------	------	------	28875	202.25	------	------	------	------

TABLE 4.—Receipts of Cabbage in Beckley by Freight: State or City from Which Shipped, Quantity, and Carrying Charges by Months, April, 1926, to March, 1927, Inclusive

Month	Total		State or City from Which Shipped			
			Hinton		Charleston	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	94189	$454.32	13625	$37.22	1300	$5.60
1926						
April	5258	16.01	4475	12.51	------	------
May	3506	10.87	3300	8.91	------	------
June	3700	9.99	3700	9.99	------	------
July	5600	25.57	1800	4.86	------	------
August	50	.14	50	.14	------	------
September	------	------	------	------	------	------
October	1300	4.91	300	.81	1000	4.10
November	24000	120.00	------	------	------	------
December	24585	122.93	------	------	------	------
1927						
January	25890	142.40	------	------	------	------
February	300	1.50	------	------	300	1.50
March	------	------	------	------	------	------

Month	State or City from Which Shipped					
	Cincinnati		Columbus		New York	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	4583	$24.21	206	$1.96	74475	$385.33
1926						
April	783	3.50	------	------	------	------
May	------	------	206	1.96	------	------
June	------	------	------	------	------	------
July	3800	20.71	------	------	------	------
August	------	------	------	------	------	------
September	------	------	------	------	------	------
October	------	------	------	------	------	------
November	------	------	------	------	24000	120.00
December	------	------	------	------	24585	122.93
1927						
January	------	------	------	------	25890	142.40
February	------	------	------	------	------	------
March	------	------	------	------	------	------

scale in this area, but reports from its production in gardens indicate that it would grow well.

Onions

Tables 5 and 6 show the receipts of onions by freight on the Beckley market. The receipts for the latter twelve months amounted to only about 70 percent of those for the year preceding.

Farmers in the New River section might well investigate the

adaptability of their soil to this crop. There was a market for onions every month in the year, and a local product might displace some of the varieties now shipped in.

Vegetables

Tables 7 and 8 show the quantity of receipts of vegetables (unclassified) by freight and express. Data of such vegetables as lettuce, corn, beans, and some of the vegetables listed in previous tables are included. It was not possible in the course of the study to classify

TABLE 5.—Receipts of Onions in Beckley by Freight: State or City from Which Shipped, Quantity, and Carrying Charges by Months, April, 1925, to March, 1926, Inclusive

Month	Total		State or City from Which Shipped			
			Hinton		Charleston	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	96912	$1105.55	29085	$83.71	900	$4.10
1925						
April	33824	517.51	------	------	------	------
May	30128	483.31	------	------	------	------
June	1680	5.05	1680	5.05	------	------
July	2050	6.05	2050	6.05	------	------
August	2670	8.03	2670	8.03	------	------
September	2935	9.40	2935	9.40	------	------
October	6750	24.06	4250	11.59	900	4.10
November	3200	9.81	2850	7.90	------	------
December	2825	8.72	2600	7.49	------	------
1926						
January	3950	12.16	3700	10.80	------	------
February	3600	12.03	3250	9.03	------	------
March	3300	9.42	3100	8.37	------	------

Month	State or City from Which Shipped			
	Cincinnati		Texas	
	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	2975	$16.92	63952	$1000.82
1925				
April	------	------	33824	517.51
May	------	------	30128	483.31
June	------	------	------	------
July	------	------	------	------
August	------	------	------	------
September	------	------	------	------
October	1600	8.37	------	------
November	350	1.91	------	------
December	225	1.23	------	------
1926				
January	250	1.36	------	------
February	350	3.00	------	------
March	200	1.05	------	------

TABLE 6.—Receipts of Onions in Beckley by Freight: State or City from Which Shipped, Quantity, and Carrying Charges by Months, April, 1926, to March, 1927, Inclusive

Month	Total		State or City from Which Shipped					
			Hinton		Charleston		Cincinnati	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	68726	$315.24	21395	$60.52	8100	$34.57	6710	$36.63
1926								
April	2765	10.07	2015	5.97	------	------	750	4.10
May	3345	13.54	2430	7.97	------	------	------	------
June	2924	10.31	2250	6.09	------	------	350	1.91
July	5310	25.13	1750	5.65	------	------	3260	17.78
August	2450	9.07	1650	4.47	------	------	700	3.83
September	3250	11.21	2600	7.25	------	------	100	.55
October	42050	207.87	7400	20.21	4000	17.68	1550	8.46
November	2000	7.43	1300	3.51	200	.82	------	------
December	432	2.68	------	------	------	------	------	------
1927								
January	3300	14.16	------	------	3000	12.30	------	------
February	900	3.77	------	------	900	3.77	------	------
March	------	------	------	------	------	------	------	------

Month	State or City from Which Shipped					
	Columbus		Indiana		New York	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	3921	$25.10	24100	$128.94	4500	$29.48
1926						
April	------	------	------	------	------	------
May	915	5.57	------	------	------	------
June	324	2.31	------	------	------	------
July	300	2.30	------	------	------	------
August	100	.77	------	------	------	------
September	550	3.41	------	------	------	------
October	500	3.10	24100	128.94	4500	29.48
November	500	3.10	------	------	------	------
December	432	2.68	------	------	------	------
1927						
January	300	1.86	------	------	------	------
February	------	------	------	------	------	------
March	------	------	------	------	------	------

these receipts; nor was it possible to separate the express charges for these vegetables from charges on other commodities in the same shipment. Total receipts for the year 1926-27 show a marked decrease from receipts for the previous corresponding period, while express receipts show a slight decrease, with a three-months' record missing.

Apples

Tables 9 and 10 show the quantity of apples received on the Beckley market for the period under consideration. It may be noted that

the receipts for the second period amounted to 82 percent of the receipts of the first year. The carrying charges, however, were about the same because of the receipt of a carload of Washington apples, bearing high freight charges.

Mixed Fruits

Table 11 shows the express receipts of fruits on the Beckley market. It was not possible to separate the records by commodities, since

TABLE 7.—Receipts of Vegetables (Unclassified) in Beckley by Freight and Express: State or City from Which Shipped, Quantity, and Carrying Charges by Months, April, 1925, to March, 1926, Inclusive

Month	Total		State or City from Which Shipped by Freight			
			Hinton		Cincinnati	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	259895	$704.95	10585	$45.02	33620	$202.93
1925						
April	------	------	------	------	------	------
May	------	------	------	------	------	------
June	55230	475.89	5230	18.89	------	------
July	55757	205.67	550	2.74	33620	202.93
August	10166	.11	20	.11	------	------
September	13666	.07	25	.07	------	------
October	25595	no r'c'rd	------	------	------	------
November	23125	.32	60	.32	------	------
December	16545	2.15	390	2.15	------	------
1926						
January	18637	6.39	1520	6.39	------	------
February	15595	8.21	1505	8.21	------	------
March	25579	6.14	1285	6.14	------	------

Month	State from Which Shipped by Frt.		Express	
	Virginia			
	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	50000	$457.00	165690	no record
1925				
April	------	------	------	------
May	------	------	------	------
June	50000	457.00	------	------
July	------	------	21587	no record
August	------	------	10146	no record
September	------	------	13641	no record
October	------	------	25595	no record
November	------	------	23065	no record
December	------	------	16155	no record
1926				
January	------	------	17117	no record
February	------	------	14090	no record
March	------	------	24294	no record

TABLE 8.—Receipts of Vegetables (Unclassified) in Beckley by Freight and Express: State or City from Which Shipped, Quantity, and Carrying Charges by Months, April, 1926, to March, 1927, Inclusive

Month	Total		City from Which Shipped by Freight			
			Hinton		Charleston	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	173481	$99.14	5166	$34.93	6300	$41.93
1926						
April	39893	4.88	945	4.88	------	------
May	30732	6.41	1216	6.41	------	------
June	21605	20.76	2515	20.76	------	------
July	20485	24.46	360	2.18	------	------
August	21954	no r'c'rd	------	------	------	------
September	3506	no r'c'rd	------	------	------	------
October	10886	13.54	------	------	2150	13.54
November	1880	12.25	130	.70	1750	11.55
December	1200	8.42	------	------	1200	8.42
1927						
January	1200	8.42	------	------	1200	8.42
February	8688	no r'c'rd	------	------	------	------
March	11452	no r'c'rd	------	------	------	------

Month	City from Which Shipped by Frt.		Express	
	Cincinnati			
	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	2325	$22.28	159690	no record
1926				
April	------	------	38948	no record
May	------	------	29516	no record
June	------	------	19090	no record
July	2325	22.28	17800	no record
August	------	------	21954	no record
September	------	------	3506	no record
October	------	------	8736	no record
November	------	------	no record	
December	------	------	no record	
1927				
January	------	------	no record	
February	------	------	8688	no record
March	------	------	11452	no record

the quantity was not given for each separate commodity. These fruits included apples, peaches, pears, plums, and grapes.

Canned Milk

Table 12 shows the receipts of canned milk on the Beckley market for the twenty-four months under consideration. The second twelve-months' period showed an increase in receipts over the first period.

Beckley consumers are not well supplied with dairy products, especially fluid milk. Several families keep one or two cows which supply them with milk. In general the dairy situation is not satisfactory. There appears to be justification for an expansion in dairying sufficient to meet the needs for whole milk. Some of the demand for canned milk might be turned to a demand for whole milk if the latter could be supplied at a reasonable price and with reasonably good service.

TABLE 9.—Receipts of Apples in Beckley by Freight: State or City from Which Shipped, Quantity, and Carrying Charges by Months, April, 1925, to March, 1926, Inclusive

Month	Total		State or City from Which Shipped					
			Hinton		Ronceverte		Cincinnati	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	353169	$1427.91	52505	$180.14	5050	$15.66	750	$6.95
1925								
April	------	------	------	------	------	------	------	------
May	------	------	------	------	------	------	------	------
June	7560	26.95	7560	26.95	------	------	------	------
July	24640	177.17	640	2.17	------	------	------	------
August	------	------	------	------	------	------	------	------
September	6200	26.53	6200	26.53	------	------	------	------
October	78610	236.01	5140	19.30	3450	10.70	------	------
November	126965	449.56	2445	10.55	800	2.48	------	------
December	33720	160.02	6740	26.64	800	2.48	------	------
1926								
January	5545	20.86	5545	20.86	------	------	------	------
February	62609	318.93	11215	28.90	------	------	450	4.31
March	7329	20.83	7020	18.24	------	------	300	2.64

Month	State or City from Which Shipped by Freight					
	Virginia		Delaware		New York	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	166740	$498.54	24000	$175.00	104124	551.62
1925						
April	------	------	------	------	------	------
May	------	------	------	------	------	------
June	------	------	------	------	------	------
July	------	------	24000	175.00	------	------
August	------	------	------	------	------	------
September	------	------	------	------	------	------
October	70020	206.01	------	------	------	------
November	96720	292.53	------	------	27000	135.00
December	------	------	------	------	26180	130.90
1926						
January	------	------	------	------	------	------
February	------	------	------	------	50944	285.72
March	------	------	------	------	------	------

TABLE 10.—Receipts of Apples in Beckley by Freight: State or City from Which Shipped, Quantity, and Carrying Charges by Months, April, 1926, to March, 1927, Inclusive

Month	Total		State or City from Which Shipped					
			Hinton		Charleston		Cincinnati	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	292491	$1469.62	55945	$108.18	27980	$126.33	1215	$6.60
1926								
April	10535	33.62	8575	22.52	------	------	1215	6.60
May	13465	52.40	11450	31.40	------	------	------	------
June	8080	23.36	7330	15.68	------	------	------	------
July	2120	4.80	2120	4.80	------	------	------	------
August	------	------	------	------	------	------	------	------
September	25055	118.19	------	------	24000	112.80	------	------
October	67992	711.84	25550	31.52	1500	5.10	------	------
November	1560	5.21	920	2.26	------	------	------	------
December	23744	171.72	------	------	2000	6.80	------	------
1927								
January	500	2.30	------	------	------	------	------	------
February	104740	268.10	------	------	480	1.63	------	------
March	34700	78.08	------	------	------	------	------	------

Month	State or City from Which Shipped							
	Columbus		Virginia		New York		Washington (State)	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	3510	$33.18	144675	$371.38	21744	$164.92	37422	$659.03
1926								
April	745	4.50	------	------	------	------	------	------
May	2015	21.00	------	------	------	------	------	------
June	750	7.68	------	------	------	------	------	------
July	------	------	------	------	------	------	------	------
August	------	------	------	------	------	------	------	------
September	------	------	1055	5.39	------	------	------	------
October	------	------	3520	16.19	------	------	37422	659.03
November	------	------	640	2.95	------	------	------	------
December	------	------	------	------	21744	164.92	------	------
1927								
January	------	------	500	2.30	------	------	------	------
February	------	------	104260	266.47	------	------	------	------
March	------	------	34700	78.08	------	------	------	------

Butter

Table 13 shows the express receipts of butter on the Beckley market for the period under consideration. No receipts by freight were noted.

Poultry and Eggs

Table 14 shows the express receipts of poultry in Beckley. No freight shipments were noted. There is no great difference in the

quantity of receipts for the two years when the three-months' records which are missing are kept in mind.

There seems to be a real opportunity for local producers to expand their poultry production sufficiently to take care of the demand, which is quite constant throughout the year.

TABLE 11.—Receipts of Fruits in Beckley by Express: Quantity by Months, April, 1925, to March, 1927, Inclusive

Month	1925 and 1926	1926 and 1927
Total	*(pounds)* 30355	*(pounds)* 3899
April	1767	250
May	1800	200
June	3500	1470
July	4030	none
August	6435	1440
September	2593	none
October	1911	none
November	2668	no record
December	1645	no record
January	3076	no record
February	250	539
March	680	none

TABLE 12.—Receipts of Canned Milk in Beckley by Freight: Quantity and Carrying Charges by Months, April, 1925, to March, 1927, Inclusive

Month	Year	Pounds	Carrying Charges
Total	1925	165712	$ 926.64
	1926	235264	1457.79
April	1925	2796	17.47
	1926	10075	63.20
May	1925	17048	31.28
	1926	45859	292.19
June	1925	6038	52.35
	1926	9797	59.50
July	1925	8969	16.29
	1926	46585	306.47
August	1925	5004	30.13
	1926	12127	64.29
September	1925	45492	291.56
	1926	8712	52.20
October	1925	7438	37.10
	1926	45068	282.23
November	1925	6672	33.14
	1926	5360	27.07
December	1925	6731	37.02
	1926	39221	258.36
January	1926	5908	34.95
	1927	3510	15.01
February	1926	4323	23.48
	1927	4770	20.32
March	1926	49293	321.87
	1927	4180	16.95

TABLE 13.—Receipts of Butter in Beckley by Express: Quantity by Months, April, 1925, to March, 1927, Inclusive

Month	1925 and 1926	1926 and 1927
Total	*(pounds)* 32326	*(pounds)* 28759
April	1681	4179
May	2500	3819
June	2200	2381
July	3203	2644
August	2692	3733
September	2661	8053
October	2378	1755
November	3469	no record
December	3200	no record
January	2608	no record
February	2342	1173
March	3392	1022

TABLE 14.—Receipts of Poultry in Beckley by Express: Quantity by Months, April, 1925, to March, 1927, Inclusive

Month	1925 and 1926	1926 and 1927
Total	*(pounds)* 23300	*(pounds)* 14497
April	501	1013
May	400	440
June	2500	187
July	3748	1062
August	3339	3478
September	2493	3679
October	2744	2847
November	1415	no record
December	1520	no record
January	2438	no record
February	908	1481
March	1294	310

TABLE 15.—Receipts of Eggs in Beckley by Express: Quantity by Months, April, 1925, to March 1927, Inclusive

Month	1925 and 1926	1926 and 1927
Total	*(cases)* 1742	*(cases)* 1432
April	198	230
May	120	114
June	150	162
July	112	191
August	137	105
September	131	260
October	141	110
November	180	no record
December	124	no record
January	177	no record
February	115	153
March	157	107

Table 15 shows the receipts of eggs on the Beckley market. The local supply never has overtaken the demand and the record would indicate that egg production could stand some expansion.

TABLE 16.—Receipts of Meats in Beckley by Express: Quantity by Months, April, 1925, to March, 1927, Inclusive

Month	1925 and 1926	1926 and 1927
	(pounds)	*(pounds)*
Total	162786	36789
April	10500	14378
May	15650	13144
June	14100	9267
July	16528	none
August	10192	none
September	14329	none
October	11657	none
November	18923	no record
December	14275	no record
January	13141	no record
February	11540	none
March	11951	none

TABLE 17.—Receipts of Feed in Beckley by Freight: Quantity and Carrying Charges by Months, April, 1925, to March, 1927, Inclusive

Month	Year	Pounds	Carrying Charges
Total	1925	4102114	$11891.18
	1926	5228825	15534.84
April	1925	226247	755.11
	1926	473287	1385.50
May	1925	373057	1039.30
	1926	461940	1091.83
June	1925	91222	312.99
	1926	434785	1150.60
July	1925	37100	117.92
	1926	263228	973.84
August	1925	323445	900.00
	1926	488953	1433.23
September	1925	371809	1025.30
	1926	342240	985.34
October	1925	405833	1155.00
	1926	473763	1486.70
November	1925	418915	1160.00
	1926	643087	1751.75
December	1925	450645	1275.00
	1926	427737	1243.86
January	1926	296139	869.40
	1927	440594	1453.98
February	1926	494843	1561.24
	1927	434404	1408.15
March	1926	612868	1719.92
	1927	344807	1165.06

Meats

Table 16 shows the receipts of meats in Beckley. The small quantity of receipts in 1926 and 1927 may be accounted for by the fact that a wholesale meat market was established at Mabscott, a neighboring town, which took care of the local demands. Receipts for this establishment came to the Mabscott station.

Grain and Mill Feeds

Table 17 shows the receipts of grain and mill feeds in Beckley. Little of the Beckley area is suited to feed production in competition with mid-western states.

SUMMARY AND DISCUSSION

Beckley and other coal towns in the southern West Virginia coal fields probably must look forward to having much of their food commodities shipped or hauled from distant points, since the areas of good farm land in the section are inadequate to meet local market needs.

There are small areas of fairly good farm land. In the hands of capable farmers these areas would find in a market such as Beckley good opportunities for profitable farming.

Summers, Monroe, and Greenbrier Counties have some excellent farm land, but the condition of the roads, together with poor railway facilities, has made it difficult for the farmers to reach the coal-field markets.

The completion of a highway system connecting this agricultural section with the coal-field markets would mean much to farmers in providing a needed market and would also provide a better and probably cheaper food supply for the inhabitants of the coal towns. It would be wise to give attention to this circumstance in planning the highway system for this part of the state.

There is need for an expansion of dairying in the area, since the supply of market milk is inadequate for the demand.

The market indicates that there is room for an expansion in many types of farm production in the area, if farmers can find land suitable for their undertaking. The Beckley market is a high market throughout the year.

Bulletin 227 February, 1930

Soybeans for Silage and for Hay

by T. E. ODLAND

Soybeans and Sudan Grass on a Farm
in Harrison Co[illegible]

UNIVERSITY OF ARIZONA
LIBRARY

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

SUMMARY

Corn and soybeans were grown both alone and in various combinations for silage. Soybeans were also grown alone at various rates and dates of planting for hay and in combination with Sudan grass, sorghum, and millet.

Soybeans grown with corn for silage did not increase the total yield per acre over corn grown alone at the same rate of planting.

The soybeans when grown with corn reduced the yield of shelled corn 6 to 8 bushels per acre.

The soybeans made up from 9.3 to 15.4 percent of the total green weight in the various corn and soybean mixtures.

The percentage of protein in the silage was increased when soybeans were grown with the corn.

The yield of protein per acre was increased when soybeans were grown with the corn.

Thie yield of total nutrients per acre was not increased when soybeans were grown with the corn.

The increase in protein per acre due to the growing of soybeans with corn was not large enough to compensate for the extra work necessary in growing the combination.

Soybeans grown alone gave practically the same yield whether grown in cultivated rows or seeded solid.

The soybeans grown alone in cultivated rows produced a crop with a higher protein content than did the soybeans seeded in solid plots.

Soybeans grown with corn did not increase the percentage of protein in the corn; neither did the corn have any influence on the protein content of the soybeans.

Soybeans planted at the rate of 6 and 8 pecks per acre produced a finer quality of hay which was more nearly free from weeds than the seeding of 4 or 5 pecks per acre. There was not much difference in yields.

Soybeans seeded May 20 and later produced hay more nearly free from weeds than when planting was done as early as May 5. Planting as late as June 25 made the crop so late that curing the hay became more difficult.

Soybeans and Sudan grass made the best combination for hay.

*Cultural Experiments With Soybeans for Silage and for Hay**

by T. E. ODLAND†

NO FARM crop introduced into West Virginia has become of such importance in so short a time as have soybeans. In the last ten years the estimated acreage has increased between five and six times.

As this crop has increased in importance and its use has become more general over the state, a number of inquiries in regard to its culture and utilization have, from time to time, been received by the State Agricultural Experiment Station. The purpose of this bulletin is to present the results of experiments conducted under West Virginia conditions and hence applicable to certain of these inquiries. These experiments include a test in which corn and soybeans were grown alone in various ways and in various combinations for silage purposes. In another experiment soybeans were grown alone and in combination with various other crops for hay. The experiments also include tests in which soybeans were sown at various rates and at different dates for hay.

One of the reasons why the soybean has met with much favor over the entire state is its adaptability to a wide range of climatic conditions. No other legume commonly grown in the state is adapted to so wide a range of soil conditions. It will thrive well on any corn soil and does better than most other common legumes on thin, acid soils.

The feeding value of soybean hay has been demonstrated in many feeding trials.[1] When cut at the proper stage and properly cured, soybean hay has about the same feeding value as alfalfa. When mixed with corn, soybeans increase the feeding value of the silage produced on account of their high protein content. The extent of this increase depends upon the proportion of soybeans in the combination.

*Submitted for publication July, 1927.
†Resigned February, 1929.
[1]W. Va. Agr. Exp. Sta. Bul. 181.

Whether or not it is advisable to grow soybeans and corn together for silage is one of the questions considered in the present report.

Soybeans also make excellent supplementary feed for sheep or hogs when fattened on corn. For this reason soybeans are often planted with corn for hogging down or for pasturing with sheep.

Crop Known for Soil Improvement Qualities

As a soil-improvement crop soybeans are not equal to red clover or alfalfa when the entire crop is removed. This circumstance may be credited in part at least to their less extensive root system. However, if the crop is plowed under or if the hay is fed and the manure is returned to the land, soybeans make an excellent soil-improvement crop. This ability of soybeans to restore fertility has won for the crop a place on the rotation systems of more and more farms.

Soybeans rank as one of the most dependable crops grown in the state. If good seed is sown and the season is an average one, a grower has fair assurance of a good crop. Soybeans are often used as a substitute crop for red clover or alfalfa that has failed to come through the winter satisfactorily. Red clover has been an uncertain crop in recent years and soybeans are finding increasing favor as a substitute for this crop.

Another important characteristic of the soybean is its seed-producing ability. The seed crop is more certain and satisfactory than that of any other legume commonly grown in the state. A yield of 15 to 20 bushels per acre is commonly obtained. Yields as high as 40 bushels per acre have been obtained in very favorable seasons in some of the experiments conducted at this Station. The seed crop also is handled more easily than most forage crops. No special machinery is needed and the seed is easily cleaned.

On many farms the practice of planting soybeans with corn for silage is followed regularly. The combination often is used also for hogging down and for sheep pasture. The argument in favor of growing the combination for silage is that a silage containing a higher percentage of protein is produced and thus the amount of concentrates that it will be necessary to buy will be lessened. This scheme is desirable if the total yield is high enough to repay one for the extra work and inconvenience in growing the combination.

The results of experiments in growing soybeans and corn together for silage have varied considerably. Some investigators have reported in favor of the combination while others have made unfavorable reports.

HISTORICAL REVIEW

At the Connecticut Agricultural Experiment Station[2] an average increase of one ton of silage and 120 pounds of protein per acre was obtained when growing the combination over corn grown alone. The authors concluded that this amount of increase would justify the planting of soybeans and corn together for silage only under certain favorable conditions.

At the Ohio Agricultural Experiment Station[3] no increase in green material per acre was obtained with the combination over corn grown alone. Two varieties of corn were grown. At the University Farm at Columbus, Ohio, the combination gave a slightly higher yield than corn alone.

The Pennsylvania Station[4] did not obtain any increase in total yield of green material per acre from the combination over corn grown alone. In their experiments the authors state that the amount of soybeans in the mixture was not enough appreciably to affect the composition of the silage in four of the six years of the trial.

Stemple[5] in a test covering a period of one year *(1915)* at the West Virginia Agricultural Experiment Station found that a combination of corn and soybeans produced an increase of 1.19 tons of green material per acre over corn alone.

METHODS USED IN WEST VIRGINIA EXPERIMENTS

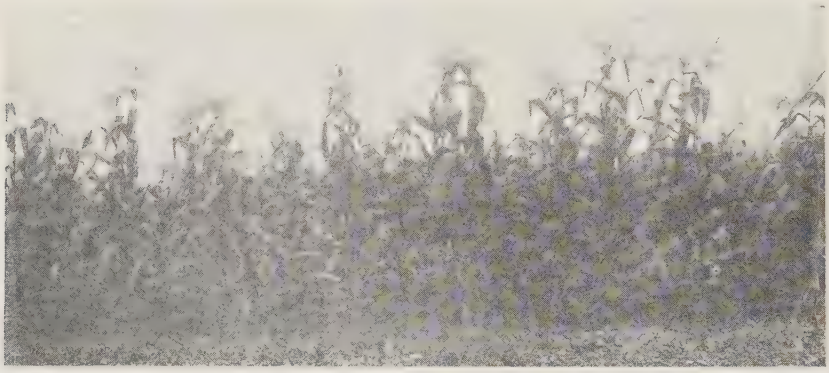
Experiments with corn and soybeans grown separately and in combination for silage, reported in the present publication, were started in the spring of 1921 and continued over a period of five years. The experiments were conducted at the Agronomy Farm near Morgantown.* In all experiments Leaming corn and Wilson soybeans were used. These were chosen as representative varieties of the two crops for this state.

The corn both alone and when in combination with soybeans was planted in plots consisting of four rows, each 8 rods in length and spaced 3½ feet apart. Only the two central rows of each plot were harvested for yield. Both the corn and soybeans when grown in combination and the corn when grown alone were planted more thickly than the desired stand and then later thinned to the various stands. The soybeans grown alone in rows were planted in plots

[2]Conn. Agr. Exp. Sta. Bul. 133.
[3]Ohio Agr. Exp. Sta. Month. Bul. XII: Nos. 5 and 6, 1922.
[4]Penn. Agr. Exp. Sta. Bul. 187.
[5]W. Va. Agr. Exp. Sta. Bul. 172.

consisting of 4 rows spaced 30 inches apart and 8 rods in length. The two central rows were used for yield determination.

Where soybeans were seeded solid at the rate of six pecks per acre the plots were one drill-width wide, or a little more than 8 feet, and the same length as the other plots. In this case the two outer drill rows on each side of the plot were cut and discarded before harvesting the rest of the plot in order to eliminate border effect as much



Corn and Soybeans grown together for Silage on the Agronomy Farm

as possible. All plots were repeated three times, making four plots of each crop, combination, or method of planting each year.

All plots were harvested at the same time and when the corn had reached the glazed stage. At that time the soybeans had well-developed seeds and some of the leaves were beginning to fall,—somewhat past the best stage to cut soybeans for hay. At harvest time the soybeans were cut and weighed immediately. In the combination crops the corn and soybeans were cut and weighed separately. A sample of about 15 pounds was taken from each plot at the time of cutting in order to determine the moisture content. Chemical analyses* of these samples were made for the years 1923, 1924, and 1925. The sample was weighed at the time it was taken and again after drying. It was dried artificially to a constant weight and then allowed to hang in a shed until it had regained equilibrium with the moisture content of the air. From the weight obtained after such treatment, the air-dry yields per plot were calculated.

*It is recognized that the type of soil will necessarily have much influence on the results obtained in experiments of this nature. The type of soil on which the Agronomy Farm is located is classified as Dekalb silt loam, of medium productivity. This soil type is representative of much of the farm land in West Virginia and therefore the results are applicable to a considerable area of the state.

After the weight of the green material had been obtained the corn was put in shocks and later husked in order to obtain the yield of shelled corn per acre. When the corn was husked a sample was taken on which the moisture content was determined. All grain yields are reported on the basis of 14 percent moisture.

Although the corn when harvested was not as mature as when ordinarily cut for grain, it was all taken at the same time. Consequently the yields may be considered comparable. The yields of shelled corn per acre would probably be somewhat higher if the corn had been left until more fully mature.

EXPERIMENTAL RESULTS

The data obtained for the various combinations, and for each of the crops grown alone, include the total yield per acre of green material, air-dry material, shelled corn, protein, and total nutrients. The percentage of soybeans in the various combinations also was determined.

Yield of Green and Air-dry Material per Acre

The yields obtained both in green and air-dry material per acre are shown in Tables 1 and 2.

The data in these tables show that when corn was grown alone at the rate of 2 stalks per hill the average yield was 7.36 tons of green material per acre; when the corn was grown at the rate of 3 stalks per hill the yield was 8.63 tons or an increase of 1.27 tons per acre in favor of the thicker planting. On the air-dry basis the yield was 0.42 tons per acre in favor of the thicker planting. While this difference in yield was not large, the increase in yield was consistent for every year of the test.

In determining whether differences in average yields between various plots were large enough to be of significance from a mathematical point of view, Student's[6] method was used in comparing the yields of various plots. According to this method the odds are 1,392 to 1 that the difference in air-dry yields obtained between these two rates of planting is significant. Under the conditions of this experiment, therefore, a stand of 3 stalks per hill may be expected to outyield corn planted at the rate of 2 stalks per hill.

---

*The author is indebted to T. J. Cochrane, formerly of the agricultural chemistry department, for making the chemical analyses.

[6]Student. "Probable error of a mean." *Biometrika* 6:1-25. 1908.

Table 1.—Yield in Tons of Green Forage per Acre of Corn and Soybeans, Grown Separately and in Various Combinations

Crop or Combination	Method and Rate of Planting	Tons of Green Forage per Acre for the Years 1921 to 1925					Average Yield 1921-25
		1921	1922	1923	1924	1925	
Corn alone	2 stalks	6.97	7.36	8.41	6.91	7.14	7.36
Corn alone	3 stalks	8.44	8.31	9.98	8.43	8.01	8.63
Corn alone	Drilled 7"	9.95	9.61	10.57	9.53	10.44	10.02
Corn alone	Drilled 14"	8.54	8.80	9.72	7.90	9.06	8.80
Corn alone	Drilled 21"	8.02	7.99	9.07	7.05	7.65	7.96
Corn and soybeans	Drilled 7"	9.58	9.21	11.41	9.63	10.75	10.12
Corn and soybeans	2 stalks corn, 1 plant soybeans	7.09	7.09	8.85	6.99	6.21	7.25
Corn and soybeans	2 stalks corn, 2 plants soybeans	7.57	7.87	8.80	7.24	6.77	7.65
Soybeans alone	In rows 30" apart	5.48	7.34	7.44	8.75	6.88	7.18
Soybeans alone	Solid, 6 pecks per acre	6.13	6.57	7.23	8.36	7.60	7.18

Table 2.—Yield in Tons of Air-dry Forage per Acre of Corn and Soybeans Grown Alone and in Various Combinations

Crop or Combination	Method and Rate of Planting	Tons of Air-dry Forage per Acre for the Years 1921 to 1925					Average Yield 1921-25
		1921	1922	1923	1924	1925	
Corn alone	2 stalks	2.62	2.26	2.29	2.08	2.24	2.30
Corn alone	3 stalks	3.15	2.73	2.80	2.37	2.52	2.72
Corn alone	Drilled 7"	3.65	3.02	2.78	2.63	2.86	2.99
Corn alone	Drilled 14"	3.06	2.77	2.77	2.12	2.84	2.71
Corn alone	Drilled 21"	2.94	2.32	2.33	1.89	2.18	2.33
Corn and soybeans	Drilled 7"	3.33	2.76	2.97	2.64	3.53	3.05
Corn and soybeans	2 stalks corn, 1 plant soybeans	2.47	2.43	2.37	1.95	2.02	2.25
Corn and soybeans	2 stalks corn, 2 plants soybeans	2.66	2.53	2.34	2.02	2.20	2.35
Soybeans alone	In rows 30" apart	1.96	2.00	2.04	2.62	2.21	2.17
Soybeans alone	Solid, 6 pecks per acre	1.93	2.20	1.95	2.34	2.35	2.15

The yields in both green and air-dry material per acre where 3 and where 2 stalks per hill were grown correspond very closely with the yields obtained on the plots where corn was planted in drills and spaced, respectively, 21 and 14 inches apart in the row. On the air-dry basis the yield of the 2-stalk plots is nearly identical with the average yield of the corn drilled 21 inches apart; the average of the 3-stalk plots is almost identical with the 14-inch planting. The number of stalks per acre is the same when 2 stalks per hill are used as when the corn is drilled at the rate of 1 stalk every 21 inches in the row. The same is true whether 3 stalks per hill are used or whether spacing 14 inches in drilled rows is employed. From these results it apparently makes no difference whether the corn is planted in drills or in hills as long as there are the same number of stalks per acre.

Where the corn was drilled at the rate of 1 stalk every 7 inches in the row the green yield was 10.02 tons and the air-dry yield 2.99 tons per acre. This is an increase over the 14-inch planting of 1.22 tons of green material or 0.28 tons of air-dry material per acre. Although this thicker planting resulted in a higher yield per acre both on the green and on the air-dry basis, the stalks were small and the proportion of grain was very much less than in the thinner plantings.

Corn and Soybeans in Combination

Each year in three series of plots soybeans were planted with the corn in various proportions. In one series corn and soybeans were planted thickly in drilled rows and thinned to a stalk of corn every 7 inches of row with one soybean plant between each two stalks of corn. The average yield for this method of planting was 10.12 tons of green material per acre or 3.05 tons on the air-dry basis, or very nearly the same average yields as for the corn grown alone at the same rate. There was only 0.1 ton difference in average yield per acre on the green basis and 0.06 ton difference on the air-dry basis. The growing of soybeans with the corn at this rate therefore neither increased nor decreased the total yield of silage per acre.

In the plots where one soybean plant was grown in each hill with two stalks of corn the average yield of green material was 7.25 tons per acre; on the air-dry basis the yield was 2.25 tons, or very nearly the same on either basis as when corn was grown alone at the rate of 2 stalks per hill. Where 2 soybean plants were grown in each hill with the corn the yields were 7.65 and 2.35 tons per acre on the green and on the air-dry basis respectively. Here again there is obviously

no difference in total yield per acre whether corn is grown alone or in combination with soybeans.

In all three sets of plots, therefore, where soybeans were grown with corn at various rates, there was neither a significant increase nor decrease in total yield of the combination as compared with corn alone when grown at the same rate as in the combination. If therefore there is any advantage in growing soybeans with corn for silage purposes it must be found in the higher feeding value which might be expected from the combination.

Soybeans Grown Alone

Soybeans were grown alone with two methods of planting. One set of plots was planted in cultivated rows 30 inches apart; the other set was drilled solid at the rate of 6 pecks per acre. The data show that over the 5-year period the average yield for the two methods of seeding was exactly the same on the green-material basis and almost so on the air-dry basis. Similar results were obtained in a single test in 1918 by Stemple.[7] The yield on both the green and the air-dry basis is only a little less than the yield of corn grown at the rate of 2 stalks per hill, or corn grown at this rate in combination with soybeans.

Although there was no difference in yields between the two methods of growing the soybeans there was considerable difference in the crop produced. Where the soybeans were drilled solid the stems were finer than when grown in rows. However, there was always a considerable proportion of weeds in the solid-sown plots, while in the soybeans grown in cultivated rows the weeds were kept out. More seed also was produced in the cultivated rows. The chemical analyses showed that the soybeans grown in rows had the higher protein content.

Proportion of Soybeans to Corn in the Combination Plots

In the plots where the corn and soybeans were grown in combination, each crop was cut and weighed separately in order to find the percentage by weight of each. Table 3 gives the average percentage of soybeans in each of the various mixtures for each year in which they were grown. The figures in this table are based on the green weights. On an air-dry basis the proportion was practically the same.

[7] W. Va. Agr. Exp. Sta. Bul. 172.

The data in this table show that, in the plots where soybeans were planted with corn that had been drilled and thinned so as to have a stalk every 7 inches in the row, the percentage of soybeans in the combined crop ranged from 12.3 percent in 1921 to 23.2 percent in 1923, with an average of 15.4 percent for the 5-year period.

Where one soybean plant was grown in each hill of corn, the percentage of soybeans in the mixture varied from 6.7 percent in 1924 to 11.5 percent in 1921, with an average of 9.3 percent for the period of the experiment.

Table 3.—Percentage by Weight (Green) of Soybeans in the Various Combinations of Corn and Soybeans

Combination and Rate	Percentage of Soybeans in Mixture for the Years 1921 to 1925					Average Percentage of Soybeans in Mixture
	1921	1922	1923	1924	1925	
Corn and soybeans, drilled 7"--	12.3	15.0	23.2	14.0	12.4	15.4
Corn 2, soybeans 1, per hill----	11.5	7.7	11.3	6.7	9.2	9.3
Corn 2, soybeans 2, per hill----	17.7	13.0	18.7	12.0	13.6	15.0

In the plots where 2 soybean plants were grown in each hill the percentage of soybeans in the mixture varied from 12.0 percent in 1924 to 18.7 percent in 1923, with an average of 15 percent.

As these figures indicate, the proportion of soybeans in the mixture varied considerably from year to year. In the two mixtures where soybeans were planted so that there were approximately equal numbers of corn and soybean plants, the soybeans made up approximately 15 percent of the mixture in each case. Where only one soybean plant was used per hill, the proportion of soybeans in the mixture was considerably less.

Yield of Shelled Corn Grown Alone

When soybeans are grown with corn and the corn is cut and husked, there is amost always a reduction in the yield of corn as compared with corn grown alone at the same rate. A number of experiment stations have reported results on such tests. At the Missouri Station[8] a reduction in yield of from 4 to 8 bushels per acre was obtained when soybeans were grown with corn in varying combinations. At the Tennessee Station[9] both cowpeas and soybeans when planted with corn reduced the yield of corn considerably.

In the experiments conducted at the West Virginia Station the yield of shelled corn for each plot was determined both where corn

[8]Mo. Agr. Exp. Sta. Bul. 220.
[9]Tenn. Agr. Exp. Sta. Bul. 137.

was grown alone and where soybeans were grown with the corn. The yields obtained on the various plots are given in Table 4.

The average yield of shelled corn on the plots where corn was grown alone with 2 stalks per hill was 40.5 bushels per acre. Where 3 stalks per hill were grown the yield was 43.5 bushels per acre, or an increase of 3 bushels per acre over the 2-stalk plots. The odds are 16 to 1 that this difference is large enough to be considered significant.

Where the corn was planted in drills and thinned to one stalk every 14 inches the yield was 41.5 bushels per acre; where the stalks were spaced 21 inches the yield was 41.6 bushels. These yields are almost identical. They are one bushel per acre more than was obtained from the 2-stalk plots and 2 bushels per acre less than the 3-stalk plots produced.

Little difference was noted among yields of shelled corn per acre whether the seed was planted in hills at the rate of 2 stalks per acre or 3 stalks per acre; or whether it was planted in drilled rows, spaced 14 inches apart or 21 inches apart. There was no apparent difference in size or quality of ears from any of these plots.

Where the corn was drilled and thinned to a stand of one stalk every 7 inches the yield averaged only 29 bushels per acre. The ears were small, with many nubbins. This rate of planting evidently was much too thick for producing a good yield of shelled corn.

Yield of Shelled Corn in Combination with Soybeans

Where one soybean plant was grown with each hill of corn the average yield was 33.4 bushels per acre, or 8.1 bushels less than when corn was planted at the same rate alone. Where two soybean plants were grown in each hill the average yield was 33.1 bushels per acre, or a reduction of 8.4 bushels compared with the plots wherein corn was grown alone. In each case the reduction was approximately 20 percent.

Where the soybeans were drilled with corn at the thickest rate used, or one stalk of corn every 7 inches and a soybean plant alternating with each stalk of corn, the average yield was 23 bushels per acre. This was 6 bushels less per acre than where the corn alone was drilled at this rate. Where the corn was planted as thickly as 7 inches apart there was considerable variation in the yield of shelled corn from year to year whether it was grown alone or in combination with soybeans. In one year the combination yielded more than did corn alone drilled at the same rate.

Table 4.—Yield in Bushels of Shelled Corn per Acre of Corn Grown Alone at Various Rates and in Combination with Soybeans

Crop or Combination	Method and Rate of Planting	Yield in Bushels per Acre for the Years 1921 to 1925					Average Yield 1921-25
		1921	1922	1923	1924	1925	
Corn alone	2 stalks per hill	51.0	40.5	37.1	33.7	40.4	40.5
Corn alone	3 stalks per hill	58.8	42.6	38.9	38.2	39.1	43.5
Corn alone	Drilled 7"	53.1	19.4	21.0	20.4	31.3	29.0
Corn alone	Drilled 14"	54.3	42.9	35.1	30.0	45.2	41.5
Corn alone	Drilled 21"	54.8	45.5	38.8	30.3	38.6	41.6
Corn and soybeans	Drilled 7"	34.9	11.7	26.6	13.6	28.2	23.0
Corn and soybeans	2 stalks corn, 1 plant soybeans	42.2	35.3	33.7	27.9	28.1	33.4
Corn and soybeans	2 stalks corn, 2 plants soybeans	42.2	36.5	30.8	26.3	29.8	33.1

Table 5.—Average Composition of Corn and Soybeans Grown Alone and in Various Combinations, 1923 to 1925 (green weight)

Crop or Combination	Method and Rate of Planting	Constituents (Percent)					
		Dry Matter	Ash	Protein	Fat	Fiber	Carbohydrates
Corn alone	2 stalks	27.07	0.99	2.03	0.65	5.71	23.40
Corn alone	3 stalks	26.36	1.05	1.95	0.63	5.47	22.73
Corn alone	Drilled 7"	25.22	1.22	1.47	0.46	6.06	22.07
Corn alone	Drilled 14"	26.65	1.07	1.82	0.64	5.97	23.12
Corn alone	Drilled 21"	24.36	0.99	1.86	0.52	5.88	20.99
Corn and soybeans	Drilled 7"	26.90	1.22	1.95	0.76	6.85	22.97
Corn and soybeans	2 stalks corn, 1 plant soybeans	26.65	1.14	2.14	0.74	6.30	22.63
Corn and soybeans	2 stalks corn, 2 plants soybeans	26.64	1.24	2.32	0.86	6.46	22.22
Soybeans alone	In rows 30" apart	27.65	1.90	4.24	1.99	9.08	19.53
Soybeans alone	Solid, 6 pecks per acre	26.68	1.92	3.27	1.41	8.89	20.08

Because of the considerable fluctuation in results from these thickly planted plots, not as much confidence can be placed in the relative difference between the corn-alone and the combination plots as can be placed in the results where a more nearly normal rate of planting was used. When corn was spaced only 7 inches apart, whether grown alone or with soybeans, so much corn was lodged some years and the growth was generally so short that relatively few good ears developed.

Composition of Silage

Since soybeans are high in protein it would be expected that where soybeans are grown with corn, the combination crop would have a higher protein content and hence the feeding value of the silage would be higher than when the corn is grown alone. Some investigators have reported a considerably higher protein content from the combination over corn alone, while others have found only slight increases due to the small percentage of soybeans in the combination.

In order to obtain data on the composition of the silage obtained, chemical analyses were made of the samples taken from the various plots in the years 1923, 1924, and 1925. Where corn and soybeans were grown in combination, separate analyses were made of each crop. The composition of the combination crop was then computed by taking into account the proportion of the total yield made up by each of the two crops. The results obtained are shown in Table 5.

The data in this table show that in the plots where corn was grown alone, the percentage of protein varied from 1.47 percent where the corn was spaced 7 inches apart in the row, to 2.03 percent where the corn was planted at the rate of 2 stalks per hill. The soybeans drilled solid averaged 3.27 percent protein, while those planted in cultivated rows averaged 4.24 percent. In the combination crops the percentage of protein ranged from 1.95 percent in the plots where the corn and soybeans were drilled 7 inches in the row, to 2.32 percent where 2 stalks of corn and 2 soybean plants were grown in each hill.

Protein Content of Silage in the Various Methods Compared

In comparing the average composition of the plots where corn was grown alone at the rate of two stalks per hill, with the plots where corn was planted at the same rate but with one soybean plant in each hill, it was shown that the composition of protein was in-

creased from 2.03 to 2.14 percent by the soybeans. This was an increase only of approximately 0.1 percent. When two soybean plants were grown with the corn the protein content was raised to 2.32 percent, or an increase of approximately 0.3 percent. When only one soybean plant was grown per hill the increase in protein content of the mixture over corn alone was very small, while the increase when 2 plants per hill were grown with the corn was somewhat higher and may be enough to account for a definite increase in the feeding value of the silage.

May 5 seeding of Soybeans on right; May 20, center; later seedings at left

When corn was grown alone and spaced 7 inches in the row the protein content of silage was 1.47 percent, or very much less than where corn was planted more nearly at the usual rates. This result might be expected from the low proportion of grain in the silage. When soybeans were grown with corn planted at this rate, the protein content was increased to 1.95 percent. In this case there was a very material increase in the protein content because of the soybeans in the mixture. The protein content of this combination, however, was only slightly higher than that of the plots where corn alone was drilled either 14 or 21 inches apart in the row. It was slightly less than the average protein percentage of the corn grown alone in 2-stalk hills, and the same as that of the corn in the 3-stalk hills.

The results obtained in these tests therefore show that where one soybean plant per hill was grown with corn at the normal rate of planting corn in hills, practically no increase in protein content over corn grown alone resulted from the combination; where two stalks were grown a small increase resulted; and where the crops were drilled thickly a considerable increase was obtained.

Where the soybeans were grown in cultivated rows there was a very marked increase in average protein content over those plots where they were sown solid. This difference in protein was approximately the same each year.

This higher protein content in the soybeans grown in cultivated rows may be due to several causes. Under cultivation the soil usually has a higher nitrate content than where it is not worked. This cultivation would tend to increase the protein content of the crop grown. The absence of weeds in the soybeans in the cultivated rows and the larger percentage of seed in these plots would also tend to produce a hay with a higher protein content than that from the solid-seeded plots. The soybeans in the solid-seeded plots also were usually a little more mature when cut than those in the cultivated rows. This difference would tend to reduce the protein content of these as compared to the soybeans from the cultivated plots.

In considering the other constituents for which the samples were analyzed, little difference is seen between the various plots in dry matter or carbohydrate content. In ash, fat, and fiber the soybeans are somewhat higher than the corn when grown alone, while the combination usually ranges between these.

Yield of Protein and of Total Nutrients per Acre

Another question in the present discussion is whether the protein yield per acre is increased by growing the combination. Data are available for the years 1923, 1924, and 1925. The results obtained are given in Table 6. Here also is shown the yield of total nutrients per acre for the various plots.

The average yields of protein for the corn grown alone at the rate of 2 stalks per hill, or spaced 7, 14, or 21 inches apart in drilled rows, did not vary significantly from each other. Although the protein content in some of these was higher than in others, differences in yield of green material per acre tended to balance this.

Where 3 stalks of corn were grown per hill there was an average increase of 38 pounds of protein per acre over the 2-stalk plots. One soybean plant per hill increased it by only 9 pounds per acre. Where 2 soybean plants were grown in each hill of corn the increase was 46 pounds per acre. The protein per acre therefore was not appreciably increased by growing one soybean plant per hill; but a significant increase resulted when 2 plants per hill were grown.

Table 6.—Yield per Acre in Pounds of Protein and of Total Nutrients of Corn and Soybeans Grown Alone and in Various Combinations

Crop or Combination	Method and Rate of Planting	Pounds per Acre of Protein and Total Nutrients for the Years 1923 to 1925						Average Pounds 1923-25	
		1923		1924		1925			
		Pro.	T. N.	Pro.	T. N.	Pro.	T. N.	Pro.	T. N.
Corn alone	2 stalks	321	4016	303	3730	286	3913	303	3886
Corn alone	3 stalks	349	4808	319	4209	354	4299	341	4429
Corn alone	Drilled 7″	283	4760	278	4704	336	5180	299	4881
Corn alone	Drilled 14″	344	4834	284	3756	343	5098	324	4563
Corn alone	Drilled 21″	305	3998	264	3355	309	3710	292	3688
Corn and soybeans	Drliled 7″	456	5285	335	4700	456	6342	416	5442
Corn and soybeans	2 stalks corn, 1 plant soybeans	354	4034	284	3479	299	3581	313	3698
Corn and soybeans	2 stalks corn, 2 plants soybeans	368	4017	329	3650	351	3816	349	3828
Soybeans alone	In rows 30″ apart	539	3489	788	4522	633	3851	653	3954
Soybeans alone	Solid, 6 pecks per acre	409	3275	544	4026	565	4188	506	3830

Table 7.—Average Composition of Corn Grown Alone and in Combination and of Soybeans Grown Alone and in Combination, 1923 to 1925 (green weight)

Crop or Combination	Method and Rate of Planting	Constituents (Percent)					
		Dry Matter	Ash	Protein	Fat	Fiber	Carbohydrates
Corn alone (average)	2 stalks; 3 stalks; 14″ drilled; 21″ drilled	26.11	1.02	1.91	0.61	5.76	22.56
Corn in combination (average)	2 corn, 1 soybean; 2 corn, 2 soybeans	26.45	1.09	1.92	0.60	6.15	22.84
Corn alone	7″ drilled	25.22	1.22	1.47	0.46	6.06	22.07
Corn with soybeans	7″ drilled	26.69	1.06	1.54	0.51	6.59	23.28
Soybeans alone	rows	27.65	1.90	4.24	1.99	9.08	19.53
Soybeans with corn (average)	2 corn, 1 soybean; 2 corn, 2 soybeans	28.02	1.92	4.44	2.28	8.19	19.37

The highest yield of protein per acre resulted where corn and soybeans were grown at the rate of corn spaced 7 inches apart in drilled rows with a soybean plant between each 2 stalks of corn. An average increase of 117 pounds of protein per acre was obtained over the plots where corn was grown alone at the same rate.

The soybeans grown in cultivated rows produced 147 pounds more protein per acre than did the soybeans grown in the plots drilled solid.

When the average yield of total nutrients per acre is considered, the data show that this yield was approximately the same for the plots where corn was grown alone at the rate of 2 stalks per hill or 21 inches apart in the row; where one or 2 soybean plants were grown in each hill of corn; and where soybeans were grown alone either in cultivated rows or drilled solid. The plots where 3 stalks of corn per hill were grown or where the stalks were spaced 14 inches apart in the row showed an increase in yield of total nutrients over the 2-stalk plots in about the same proportion as the increase in yield of green material.

The yield of total nutrients per acre was highest in the plot where soybeans were planted with corn and the corn spaced 7 inches apart in the row. Although this combination produced the highest yield of total nutrients as well as the highest yield of protein per acre, this method of planting resulted in much lodged material that was difficult to harvest.

Composition of Corn and Soybeans Alone and in Combination

What effect, if any, does the growing of corn and soybeans in combination have upon the composition of each of these crops? Is the protein content of the corn increased?

Lyon[10] at the New York (Cornell) Experiment Station found that the protein content of several non-legumes when grown in combination with red clover and alfalfa was increased. The Pennsylvania Station[11] did not find any increase in the protein content of corn when grown with soybeans.

The results obtained in the experiments reported in the present bulletin are presented in Table 7.

In getting the average protein content of corn grown alone, the average percent was used of the plots where corn was grown in 2- and 3-stalk hills and also where it was spaced 14 and 21 inches apart in

[10]N. Y. (Cornell) Agr. Exp. Sta. Bul. 447.
[11]Penna. Agr. Exp. Sta. Bul. 167.

drilled rows. The corn grown alone in drilled rows and spaced 7 inches apart was not included in this average since it was much lower than the others. For the protein content of the corn grown in combination, those plots are averaged where one and two soybean plants per hill were grown with the corn.

The average protein content of the corn grown alone was 1.91 percent and of the corn grown in combination with soybeans was 1.92 percent. Obviously the growing of soybeans with the corn in this case had no influence on the protein content of the corn. Corn grown alone and spaced 7 inches apart in the row averaged 1.47 percent, and when soybeans were grown with the corn the protein content of the corn was 1.54 percent. Again no appreciable increase in the protein content of the corn was noted as a result of growing soybeans with it.

In order to determine what effect the growing of the combination had upon the composition of soybeans, the composition of the legume grown alone in drill rows was compared with the average of the soybeans grown with corn at the rates of one and of two plants per hill. This is probably the best comparison that can be made among the various combinations in this test. The protein content of the soybeans grown alone was 4.24 percent and where grown in combination with corn, 4.44 percent. This difference is small and probably of no significance. It would seem from these results that the growing of the combined crops did not have any influence on the protein content of either the corn or the soybeans.

DISCUSSION

The growing of corn and soybeans together for silage would hardly seem a justifiable practice from the results obtained in these experiments. Growing the combination did not increase the total yield per acre of silage while the protein content of the combined crop was only a little higher than where corn was grown alone. This result was due largely to the small proportion of soybeans in the combination. The yield of protein per acre was increased only to a small extent, while the yield of total nutrients per acre was not increased. The proportion of soybeans in the corn varied considerably from year to year even under these controlled conditions. In actual practice it would therefore be difficult to estimate to what extent the composition of the silage would be affected by growing the two crops together.

The growing of the combination involves extra work in planting, culture, and harvesting. The increases obtained do not justify this additional work.

Under the conditions of this experiment, where soybeans grown alone produced practically the same tonnage per acre as the corn grown alone it would seem a much more desirable practice to grow the two crops separately and then mix them in the desired proportion when filling the silo. In this way the composition of the silage can be much more satisfactorily controlled.

The results obtained indicate that for silage the corn grown alone should be planted at the rate of about 3 stalks per hill or spaced about 14 inches apart in drilled rows. The planting of the corn at the rate of 2 stalks per hill or spaced 21 inches apart in the row did not produce as good yields as the heavier planting. Where the corn was grown at the rate of 1 stalk every 7 inches in the drilled row, more tonnage was obtained per acre, but the feeding value was considerably less per unit of weight because of the low proportion of grain produced.

Where weeds are troublesome it will probably be advisable to grow the soybeans in cultivated rows for silage. Although a coarser growth results than where the crop is drilled solid, this is not an important factor if the beans are to be used for silage.

SOYBEANS FOR HAY

Soybeans are more extensively used in West Virginia for hay than for any other purpose. As a hay crop soybeans compare very favorably with both red clover and alfalfa. Feeding trials conducted by the department of dairy husbandry at this Station[12] gave results indicating that, properly handled, soybean hay is equal in feeding value to a good grade of alfalfa hay. The yields of soybeans also compare very favorably with other forage crops commonly grown. Soybeans are also the most dependable legume grown in the state. Good yields are often obtained on land where it is difficult, if not impossible, to get a good stand of either red clover or alfalfa.

Several questions often arise with respect to the best methods of growing soybeans when they are to be used for hay. Among these are: What is the proper rate of planting the crop? When is the proper time to plant, and are there some crops which may be grown to advantage in combination with the soybeans for hay? In an endeavor

[12]W. Va. Agr. Exp. Sta. Bul. 181.

to answer these questions the following experiments were started. In an earlier test conducted at this Station,[13] results were obtained over periods of one and two years which gave some indications of what might be expected.

METHODS USED IN EXPERIMENTS

In the experiments where the soybeans were planted at various rates of seeding per acre and also where different dates of planting were used, the plots were planted in solidly drilled plots one drill-width wide and eight rods in length, making a plot approximately 1/40 acre in size. The two outside drill rows of each plot were cut and discarded before harvest each year to eliminate border effect as far as possible.

In the date-of-planting experiment the plots were planted at a uniform rate of 8 pecks per acre.

Where soybeans were grown in combination with various other crops the soybeans were planted in drill rows spaced 28 inches apart. At the first cultivation or when the soybeans were about 3 inches in height, the other crops were planted between the rows of soybeans. The millet was sown broadcast while the sorghum and Sudan grass were seeded with a garden seeder. Only the two center rows of each plot and the corresponding interplanted crops were used for yield determination.

Four plots of each rate and date of planting, as well as of different combinations of crops, were grown each year. The yields were determined by weighing the hay in the field when it was considered properly cured. A sample was taken at this time in order to determine the moisture content. In drying, this sample was handled in the same manner as has been described for the silage samples. All yields were reported on an air-dry basis. Had these yields been reported as field-cured hay they would have averaged about 15 percent higher.

Wilson soybeans were used in all experiments.

Rate of Planting

The yields obtained in the rate-of-planting experiment are given in Table 8.

The data in Table 8 show that there was little difference in yield between the various rates of planting. The yields ranged from 2.12

[13] W. Va. Agr. Exp. Sta. Bul. 172.

tons of air-dry hay per acre for the 5-peck seeding to 2.23 tons for the 8-peck seeding. The increase of the 8-peck seeding was only about one-tenth ton of air-dry hay per acre over the 4- and 5-peck seedings. The 6-peck seeding was intermediate between the 8-peck and the thinner seedings.

Although little difference was noted in the yields obtained from

Table 8.—Yield in Tons per Acre of Air-dry Hay from Soybeans Planted at Various Rates

Rate of Planting in Pecks per Acre	Yield in Tons per Acre of Air-dry Hay for the Years 1921 to 1925					Average Yield per Acre 1921-25
	1921	1922	1923	1924	1925	
4 pecks	2.49	1.99	2.15	1.65	2.40	2.14
5 pecks	2.36	2.18	2.08	1.57	2.40	2.12
6 pecks	2.50	2.25	2.15	1.63	2.36	2.18
8 pecks	2.53	2.36	2.14	1.69	2.45	2.23

the plots planted at various rates, there was a very striking difference between them in the quality of the hay produced and in the amount of weeds in the hay. Where only 4 or 5 pecks were seeded the hay produced was considerably coarser than when 8 pecks per acre were seeded. With the 6-peck seeding the hay was intermediate in this respect. The most marked difference, however, was found in the amount of weeds in the hay. Where only 4 or 5 pecks were seeded the hay generally consisted of a considerable proportion of weeds. Although there were some weeds in the hay when 8 pecks per acre were seeded, the proportion was very much less. In this respect also the 6-peck seeding was intermediate between the thinner rates of seeding and the 8-peck seeding.

The best rate of planting for soybeans will depend somewhat on the variety and the condition of the land. With large-seeded varieties like Mammoth Yellow it is necessary to plant at a heavier rate than with a small-seeded variety like the Peking. On land that is inclined to be weedy the soybeans should be planted more thickly than where the land is comparatively free from weeds.

With the Wilson soybean, a medium-size bean, it would seem advisable to plant from 6 to 8 pecks per acre. Where the land is inclined to be weedy the heavier planting should be used.

Time of Planting

The results obtained when the soybeans were planted at different dates are given in Table 9.

The yields in air-dry hay ranged from 1.93 tons per acre for the

Table 9.—Yield in Tons per Acre of Air-dry Hay from Soybeans Planted on Various Dates

Date of Planting	Average Date Harvested	Yield in Tons per Acre of Air-dry Hay for the Years 1925 to 1927			Average Yield per Acre 1925-27
		1925	1926	1927	
May 5	Aug. 25	1.88	2.36	2.82	2.35
May 20	Sept. 2	1.72	2.79	2.37	2.29
June 1	Sept. 8	1.79	2.66	1.92	2.12
June 10	Sept. 12	1.93	2.16	2.21	2.10
June 25	Sept. 20	1.79	2.27	1.77	1.95
July 10	Oct. 2	1.32	2.43	2.03	1.93

Table 10.—Yield in Tons per Acre of Air-dry Hay from Soybeans Grown Alone and in Various Combinations

Crop or Combination	Yield in Tons per Acre of Air-dry Hay for the Years 1921 to 1925					Average Yield per Acre 1921-25
	1921	1922	1923	1924	1925	
Soybeans alone	3.15	2.60	1.84	1.45	1.88	2.18
Soybeans and millet	3.03	2.28	1.95	2.50	1.79	2.11
Soybeans and Sudan grass	3.12	2.11	1.93	1.28	2.23	2.13
Soybeans and sorghum	2.89	2.01	1.80	1.35	2.32	2.07

July 10 seeding to 2.35 tons when seeded May 5. The yields fluctuated somewhat from year to year, depending on the season. Although the difference in actual yield is not great between the different dates, there were marked differences in the quality of the hay produced. When the soybeans were planted as early as May 5 there was a much higher percentage of weeds in the hay each year than when they were planted at a later date. The soybean does not make a vigorous growth until the soil is thoroughly warmed. Planting earlier gives many weeds an opportunity to become established before the soybeans can furnish sufficient competition.

Planted as late as July 10 the beans were so late in maturing sufficiently to cut for hay that considerable difficulty was encountered in curing them. The same was true to a lesser extent when they were planted June 25.

From these experiments it would seem that for best results under West Virginia conditions, soybeans should be planted sometime between the middle of May and the middle of June. In earlier plantings weeds are likely to cause difficulty, while planting later than the middle of June makes the beans so late in maturing that the curing of the hay gives considerable trouble.

Soybeans in Combination for Hay

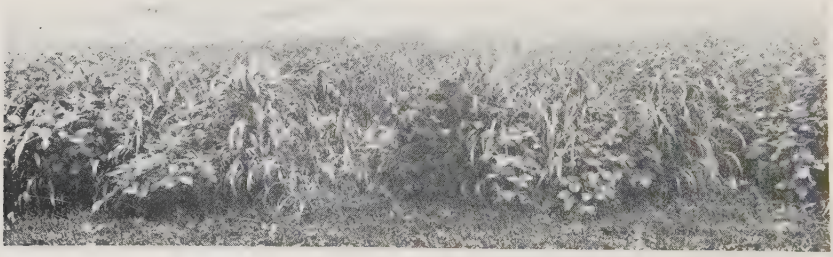
Soybeans are more difficult to cure than the ordinary hay crops. For that reason it is sometimes desired to grow some other crops with

them in order to facilitate curing. If a satisfactory crop can be found to grow with the soybeans the combined crop would also be easier to cut and handle, since the companion crop would tend to keep the soybeans from lodging. Among crops that are often suggested as suitable for growing with soybeans for hay are Sudan grass, sorghum, and millet. In order to test out the value of these crops when grown in combination with soybeans for hay, each one was grown with soybeans, and the yields determined. The results obtained are shown in Table 10.

As the data in this table show, there was little difference in yield between soybeans grown alone and any of the various combinations. The yields ranged from 2.07 tons of air-dry hay per acre for the combination of soybeans and sorghum to 2.18 tons when soybeans were grown alone.

Of these combinations the Sudan grass and soybeans made the most desirable mixture. Millet was not satisfactory, largely because it reached maturity much earlier than the soybeans. Even when planted after the soybeans were 3 or 4 inches high it was ready to cut 10 days before the soybeans had matured sufficiently for hay. Sorghum, although maturing more nearly with the soybeans, was too coarse for hay. This combination also cured very slowly. On account of its coarseness and the difficulty in curing, this combination cannot be recommended.

While the Sudan grass and soybean combination did not produce a heavier yield than soybeans grown alone, the combination proved to be more easily cured and was handled more easily than soybeans grown alone. This combination has done remarkably well in some trials in other parts of the state, especially where the soil is rich. On thin soils there is probably not much to be gained by growing the combination over soybeans alone. On bottom soils of high fertility the combination makes an excellent crop for hay.



Soybeans with Millet (right), Sudan grass (center), and Sorghum (left)

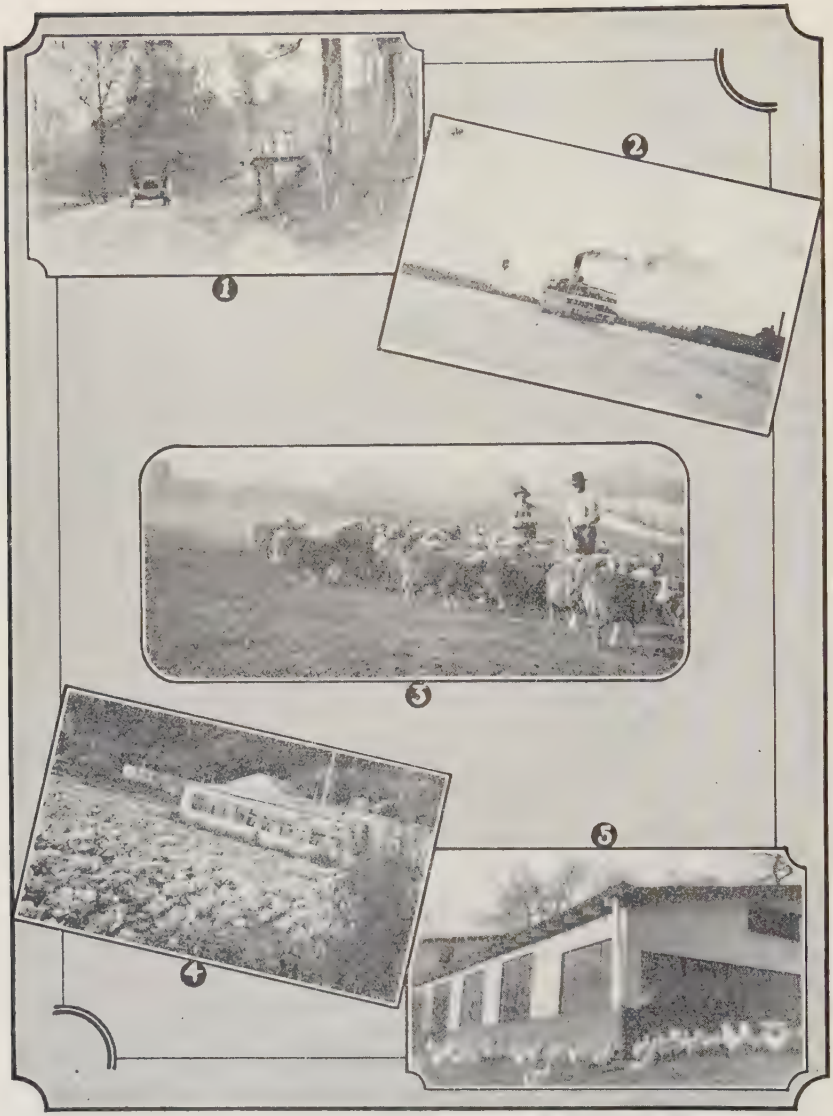
Bulletin 228 February, 1930

Adjusting Agricultural Production and Distribution in the Wheeling Area to Meet Home Market Demands

by W. W. ARMENTROUT

Extent of the Wheeling Area

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN



1. Waiting for the milk truck. Good roads made this possible.
2. Freight boats, plying the Ohio River, serve Wheeling.
3. Fine-wool sheep abound in this section.
4. A greenhouse adds value to small truck farms producing vegetables for the Wheeling market.
5. There are several commercial poultry flocks in the Wheeling area.

*Adjusting Agricultural Production and Distribution to Meet Home Market Demands in the Wheeling Area**

by W. W. ARMENTROUT

THIS report is the fourth of a series of studies of consumption of farm products in the larger cities of West Virginia and of production in the agricultural sections surrounding them.[1]

It is the report of a study of receipts of food commodities in Wheeling for a twelve-months' period beginning June 1, 1925, and ending May 31, 1926. Because of the geographical location of Wheeling, with very little of its agricultural section lying within the borders of West Virginia, no detailed study was made of nearby farm production. While Ohio County, in which Wheeling is situated, contributes considerably to the food supply of the city, it is apparent to any one familiar with the section that a large part of the locally produced commodities which reach the market come from the neighboring states of Ohio and Pennsylvania.[2]

The study was limited to obtaining (1) a record of the quantity of certain food commodities which passed through the Wheeling market, exclusive of locally produced goods transported over highways; (2) the section of the country from which the commodities came; and (3) the transportation charges.

---

*Submitted for publication August, 1927.

[1]Studies of the Charleston, Clarksburg, and Beckley areas are reported in W. Va. Agr. Exp. Sta. Bulletins 188, 212, and 226, respectively.

[2]No satisfactory plans were formulated with Ohio and Pennsylvania for a cooperative study. It seemed probable that data on local production such as could be obtained in the limited Wheeling area confined to West Virginia might prove misleading.

The quantity of various commodities coming on the market indicated a demand which was not satisfied by local production. A record of the section of country from which the commodities came will enable local producers to locate their competitors and provide a basis for studying their production costs. The transportation charges show the advantage which nearness to market affords local producers over their competitors.

This study is limited in character. While a knowledge of market demand in terms of quantity is one important guide to production, the producer should also know the market demand in terms of variety and quality of product, as well as his own cost of production in comparison with that of his competitors. There is, therefore, need that this study be continued to cover the market demands in terms of variety, quality, grade and pack, and production costs.

PURPOSE OF THE STUDY

The purpose of this and similar studies has been stated in Bulletins 188 and 212. Shifts in population and changes in production in competing sections are among the factors which make adjustments in farm production desirable from time to time if the greatest returns are to be obtained. While industry faces the need for continual changes, the size of the unit makes changes easier than in agriculture. The chief aim of the present report is to present information not readily obtainable by the individual farmer which may help farmers in West Virginia to adjust their production to meet changing conditions.

SOURCES OF DATA

The data on freight receipts were taken from the station records of the Wheeling stations of the Baltimore and Ohio Railroad, the Pennsylvania Railroad, and the Wheeling and Lake Erie Railway. Records of express receipts were obtained from the division accounting offices of the American Railway Express Company, located in Pittsburgh. Records of receipts by boat were obtained from freight records on the "Senator Cordill" and the "Helen E" freighters.[3]

The method used in this study and the source of the data make it possible to present accurately the section of country from which commodities came, the quantity of receipts, and the carrying charges.

[3]A complete record of receipts for all boats serving the Wheeling market was not available.

AGRICULTURE OF THE WHEELING AREA

Wheeling with its suburbs covers a large part of Ohio County. In recent years there has been extensive suburban development; people of means have built homes, some of them estates, out in the open country. This movement has resulted in increased land values. Consequently, under the present system of farming, values placed on the land are out of all proportion to its earning capacity as farm land. Some land has changed hands at these high prices, while much of the remaining farm land has assumed suburban values and is held and taxed accordingly. Under such conditions it is discouraging to attempt to show adequate earning powers for the land when used for agricultural purposes.

Most of the farm land in Ohio County is rolling or hilly.

There is a considerable acreage of fertile land in Ohio County well adapted for agricultural purposes. If the owner has not paid suburban prices for it and is willing to discount its paper value to the level of agricultural land value, he should be able to realize at least average returns from it.

The greater part of the land in Ohio County is hilly to rolling, but much of it has a good deep soil. Three or four sections of creek bottom in the county are well adapted to truck farming. Good farming sections are also found to the north in Brooke County and to the south in Marshall and Wetzel Counties, West Virginia. Across the Ohio River in Ohio lies a splendid farming section with a network of hard-surfaced highways which make the Wheeling market readily accessible.

Dairy farming ranks first in importance in Ohio County. In recent years it has shown rapid development in neighboring West Virginia counties as well as across the Ohio River. There is considerable truck farming in the region but indications are that such farming has lost rather than gained in favor, probably because much of the good truck land near Wheeling has been taken over for factory sites and for summer camps.

There are several specialized poultry farms, and the farm flock is an important source of income to a majority of the farmers. There are a number of commercial orchards in Brooke County and also across the river in Ohio. Sheep grazing holds considerable importance in the area, but it contributes little to the food supply, since the fine-wool breeds predominate.

RAILWAYS, HIGHWAYS, AND POPULATION

Wheeling is served by three railroads—the Baltimore and Ohio Railroad, the Pennsylvania Railroad, and the Wheeling and Lake Erie Railway. Boats ply the Ohio and Kanawha Rivers from Pittsburgh to Charleston, West Virginia, and the Ohio River to Cincinnati, and two or three small freight boats make shorter runs down the Ohio River from Wheeling.

The city is served by a highway system which reaches far out into the agricultural sections and makes it possible for producers, though miles away, easily to market their products by truck.

The population of Wheeling is about 56,000. Its wholesale groceries serve a population of approximately 360,000.[4]

RECEIPTS OF FOOD COMMODITIES IN WHEELING

The commodities included in this study are potatoes, cabbage, onions, lettuce, tomatoes, beans, corn, melons, miscellaneous vegetables, apples, peaches, grapes, poultry, eggs, milk (condensed), butter, cheese, hay, grain and mill feeds, cattle, and hogs.

Each of these commodities was being produced in some quantity in the agricultural area surrounding Wheeling, the area being more or less suited to such production in so far as physical adaptations are concerned.

These data do not show the full market demands, since the locally produced commodities which reached the market were not considered.

[4] *Atlas of Wholesale Grocery Territories*, U. S. Department of Commerce, 1927.

On the other hand, not all the commodities shown as received in Wheeling were consumed there, but were consumed within Wheeling's trade area. This circumstance, however, does not affect the significance of these data as a measure of the market demand.

Potatoes

Table 1 shows the receipts of potatoes in Wheeling by freight and by boat for the twelve-months' period beginning June 1, 1925, and ending May 31, 1926.

The receipts totalled 18,962,991 pounds or 316,046 bushels. Of this quantity 266,688 pounds, or 4,445 bushels came from points in West Virginia. This is about 1.4 percent of the total.

West Virginia supplied 8 percent of the potatoes received in Clarksburg during the preceding twelve-months' period.[5] There was no noticeable shortage in yield of potatoes during the later period.

During the four-months' period, August, September, October and November, over which most of the West Virginia potatoes are marketed, Wheeling received 7,135,861 pounds, 3.7 percent of which was shipped from points in West Virginia. During this same period of the previous year West Virginia supplied approximately 20 percent of the potatoes received in Clarksburg.[6]

Carrying charges on potatoes amounted to $94,615.45, or an average of 50c per cwt. The average carrying charges on potatoes received from West Virginia were 28c per cwt. This gives West Virginia producers a margin of 22c in transportation costs over their competitors, or practically the same advantage found for West Virginia producers on the Clarksburg market.[7]

No new data on cost of production or prices of potatoes have been collected by this Station since the publication of the Clarksburg study. The data on cost of production and prices as presented in West Virginia Agricultural Experiment Station Bulletin 212, pages 17-26, are applicable to the Wheeling area.

West Virginia producers have scarcely touched the potato market of Wheeling. From previous studies as well as several known cases of profitable potato production, there appears to be ample justification for promoting potato production in sections of the state where physical conditions are adapted to their culture.

---

[5]W. Va. Agr. Exp. Sta. Bul. 212, p. 11.
[6]W. Va. Agr. Exp. Sta. Bul. 212, p. 15.
[7]W. Va. Agr. Exp. Sta. Bul. 212, p. 17.

TABLE 1.—Receipts of Potatoes in Wheeling by Freight and Boat: Origin of Shipment, Quantity, and Carrying Charges by Months, June, 1925, to May, 1926, Inclusive

Method of Transportation, and Origin of Shipment by Freight	Total		1925									
			June		July		August		September		October	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	18962991	$94615.45	2442276	$11725.58	1723408	$7306.81	1696484	$7704.40	1371310	$6605.36	2727680	$12310.40
FREIGHT:												
Virginia	2934045	12184.23	1056040	4437.79	1526380	6260.82	259555	1051.20	62040	294.78	30030	139.64
Massachusetts	165000	1282.40	132000	1062.95	33000	219.45	-------	-------	-------	-------	-------	-------
North Carolina	251185	1375.65	156685	871.65	-------	-------	94500	504.00	-------	-------	-------	-------
Maine	665795	4109.62	91550	556.26	107250	619.17	-------	-------	137410	831.31	120635	718.82
Michigan	1882470	6935.93	89600	343.58	-------	-------	30000	102.00	150000	526.50	584500	2161.68
Georgia	30000	211.50	30000	211.50	-------	-------	-------	-------	-------	-------	-------	-------
Alabama	174440	1255.97	24400	175.68	-------	-------	-------	-------	-------	-------	-------	-------
South Carolina	594945	3363.49	594945	3363.49	-------	-------	-------	-------	-------	-------	-------	-------
New York	875626	2588.63	209156	575.18	-------	-------	-------	-------	124250	416.69	207840	596.92
West Virginia	266683	758.50	57900	127.50	-------	-------	64700	192.64	120150	384.46	18896	42.36
Minnesota	6407390	36906.44	-------	-------	30000	144.00	932400	4667.05	744100	3972.74	1056840	6059.69
Pittsburgh*	563221	1433.03	-------	-------	2718	10.74	-------	-------	-------	-------	182828	593.05
Chicago*	168000	942.40	-------	-------	-------	-------	30000	178.80	-------	-------	30000	186.00
New Jersey	133364	422.24	-------	-------	-------	-------	61004	223.24	-------	-------	-------	-------
Maryland	183991	621.08	-------	-------	-------	-------	180165	607.27	-------	-------	466	1.71
Mississippi	30000	153.00	-------	-------	-------	-------	30000	153.00	-------	-------	-------	-------
Iowa	30000	172.50	-------	-------	-------	-------	-------	-------	30000	172.50	-------	-------
Indiana	299100	1426.82	-------	-------	-------	-------	-------	-------	-------	-------	73050	362.64
Pennsylvania	228100	658.22	-------	-------	-------	-------	-------	-------	-------	-------	114710	322.30
Ohio	307372	752.24	-------	-------	-------	-------	-------	-------	-------	-------	205855	530.29
North Dakota	804040	5477.36	-------	-------	-------	-------	-------	-------	-------	-------	72000	456.80
Wisconsin	1625920	7954.58	-------	-------	-------	-------	-------	-------	-------	-------	30000	133.50
Idaho	30280	400.97	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Texas	128474	1949.32	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Florida	146365	1191.57	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
BOAT	42180	87.71	-------	-------	24060	52.62	14160	25.20	3360	6.38	-------	-------

*Wholesale market.

Method of Transportation	1925				1926									
	November		December		January		February		March		April		May	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	1340387	$5373.07	1061282	$5401.21	1313110	$6744.04	1077070	$6090.39	1926095	$10928.21	829694	$5622.75	1454195	$8298.23
FRT.:														
Va.														
Mass.														
N. Car.														
Me.	2350	252.75					90600	493.81	40000	336.50	36000	301.00		
Mich.	391650	1591.24	273000	945.75	117000	388.05	80100	267.15			99120	418.20	67500	281.78
Ga.														
Ala.													150040	1080.29
S. Car.														
N. Y.	44800	132.20	72860	259.05	216720	608.64								
W. Va.	5042	11.54												
Minn.	360000	2157.90	252000	1544.00	540000	3337.00	543000	3465.45	1142000	6864.00	176800	1317.72	630250	3376.89
Pgh.*	264740	541.50							16095	41.31	43800	28.47	53049	112.56
Chgo.*	36000	244.80			36000	241.40			36000	91.40				
N. J.			72360	199.00										
Md.	3360	12.10												
Miss.														
Ia.														
Ind.	36000	157.10			73050	325.93					36000	282.60	81000	298.55
Penn.			72180	223.76			36180	112.16						
Ohio	40395	139.80	122	.30			25000	68.75			36000	13.10		
N. D.			180480	1278.98	109560	769.48	78000	552.90	76000	514.00	252000	1682.00	36000	223.20
Wis.	116050	626.74	108000	549.40	220780	1073.54	223590	1126.67	616000	3081.00	72000	356.40	239500	1007.33
Ida.			30280	400.97										
Tex.											77974	1223.26	50500	726.06
Fla.													146365	1191.57
BOAT:							600	3.50						

*Wholesale market.

TABLE 2.—Receipts of Onions in Wheeling by Freight: Origin of Shipment, Quantity, and Carrying Charges by Months, June, 1925, to May, 1926, Inclusive

Origin of Shipment	Total		1925									
			June		July		August		September		October	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	2166811	$10125.01	141368	$1382.98	184180	$ 617.35	206425	$ 645.01	260150	$ 734.17	210487	$ 658.50
Pittsburgh*	484187	1242.15	46950	119.59	99575	253.98	57600	146.88	68600	174.93	30181	77.00
New York	280585	990.00	2690	12.11	11505	49.07	74760	301.10	71560	235.35		
Ohio	445071	1209.95					49125	105.78	68390	167.05	25706	74.53
Massachusetts	86488	932.78	61488	841.53			25000	91.25				
California	60489	866.37	30240	409.75								
Illinois	73100	314.30			73100	314.30						
Indiana	419300	1360.17							51600	156.84	154600	506.97
Michigan	77900	268.06										
Wisconsin	25000	107.50										
Texas	214700	2833.73										

Origin of Shipment	1925				1926									
	November		December		January		February		March		April		May	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Charges
Total	423150	$1324.84	43643	$ 128.91	106058	$ 315.50	210560	$ 628.97	133850	$ 393.33	63316	$ 832.53	183624	$2461.92
Pgh.*	34250	87.21	18578	48.70	55993	142.79	58510	157.87	11950	28.10	2000	5.10		
N. Y.	22500	81.60	25065	80.21	25065	80.21	22500	81.60	25000	68.75				
Ohio	172400	512.11					104550	282.00	24900	68.48				
Mass.														
Cal.													30240	456.62
Ill.														
Ind.	140100	453.66			25000	92.50			48000	145.20				
Mich.	53900	185.26							24000	82.80				
Wis.							25000	107.50						
Tex.											61316	828.43	153384	3005.30

*Wholesale market.

Onions

Table 2 shows the receipts of onions on the Wheeling market, amounting to 2,166,811 pounds, with carrying charges of $10,125.01. West Virginia did not supply any of this quantity. Ohio supplied more onions than any other state. Indiana ranked second.

Cabbage

Table 3 shows the receipts of 2,876,676 pounds of cabbage, with carrying charges amounting to $16,903.00. New York ranks first in quantity of shipments. Ohio supplied a small quantity (77,000 pounds), while no shipments came from West Virginia. Shipments of cabbage were received every month of the year,—abundant evidence of opportunity to increase local production at any period when climatic conditions permit.

Tomatoes

Table 4 shows the receipts of tomatoes on the Wheeling market. A total of 864,333 pounds, with carrying charges amounting to $7,322.74, were received. Texas contributed more than any other state, while only a few came from West Virginia and Ohio. At the time home grown tomatoes were in season, however, very few were received from producing areas other than Ohio and West Virginia. Some tomatoes were received from the wholesale markets of Pittsburgh during each month of the year. Most of the tomatoes shown as express receipts came from Pittsburgh and points in Ohio. The boat shipments for the most part came from the Marietta, Ohio, section, with very few from the West Virginia side.

The Wheeling market presents conditions parallel with those of the Clarksburg and Charleston markets in the matter of tomato supply. Local production practically takes care of demand during the local producing season. Any material increase should occur in "out-of-season" production, but sufficient data are not at hand to judge the profitableness of such an undertaking.

Lettuce

In Table 5 the receipts of lettuce on the Wheeling market are presented. The receipts by express and freight amounted to 1,122,098 pounds, with carrying charges of $12,210.37. Some lettuce was received during each month of the year. Express shipments came princi-

TABLE 3.—Receipts of Cabbage in Wheeling by Freight: Origin of Shipment, Quantity, and Carrying Charges by Months, June, 1925, to May, 1926, Inclusive

Origin of Shipment	Total		1925									
			June		July		August		September		October	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	2876676	$16903.00	173825	$1061.63	25850	$ 122.55	24700	$ 117.32	169525	$ 701.44	601560	$ 1850.53
Pittsburgh*	1039626	4525.91	105725	502.19	25850	122.55	24700	117.32	92585	439.85	220425	737.76
Virginia	22109	162.20	22100	162.20								
New York	1050795	2883.15							49620	136.46	301575	829.33
Ohio	77320	260.93	24000	80.40					27320	125.13	26000	85.40
Michigan	25700	89.96									25700	89.96
Texas	352425	5560.54										
Alabama	50485	597.28										
South Carolina	101320	1123.66										
Kentucky	21735	246.05										
Mississippi	107310	1335.24	22000	346.84								
Wisconsin	27860	108.03									27860	108.08

Origin of Shipment	1925				1926									
	November		December		January		February		March		April		May	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	238190	$ 741.86	285930	$ 883.87	334902	$1035.43	136458	$ 558.93	267251	$ 2723.86	279740	$3622.53	338745	$3483.05
Pgh.*	25500	121.12	56500	268.37	153872	628.25	60008	284.99	114736	544.82	56500	268.37	103225	490.32
Va.														
N. Y.	212690	620.74	229430	615.50	181030	407.18	76450	273.94						
Ohio														
Mich.														
Tex.									152515	2179.04	149640	2528.06	50270	853.44
Ala.													50485	597.28
S. Car.											73600	826.10	27720	307.56
Ky.													21735	246.05
Miss.													85310	988.40
Wis.														

*Wholesale market.

TABLE 4.—Receipts of Tomatoes in Wheeling by Freight, Boat, and Express: Origin of Shipment, Quantity, and Carrying Charges by Months, June, 1925, to May, 1926, Inclusive

Method of Transportation, and Origin of Shipment by Freight	Total		1925									
			June		July		August		September		October	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	864333	$7322.74	465234	$5447.93	211211	$ 952.94	65362	$ 361.37	2856	$ 12.17	5130	$ 27.15
FREIGHT:												
Pittsburgh*	244985	1084.61	81170	329.27	39915	183.52	4500	21.37	-------	-------	4860	23.27
Mississippi	105540	1006.61	83000	782.34	22540	224.27	-------	-------	-------	-------	-------	-------
Texas	280904	4172.02	280904	4172.02	-------	-------	-------	-------	-------	-------	-------	-------
Tennessee	41160	335.45	20130	164.30	21000	171.15	-------	-------	-------	-------	-------	-------
Indiana	42000	212.00	-------	-------	42000	212.00	-------	-------	-------	-------	-------	-------
BOAT	71580	127.10	-------	-------	40140	66.70	28920	52.90	2520	7.50	-------	-------
EXPRESS	78164	384.95	-------	-------	45616	89.30	31942	287.10	336	4.67	270	3.88

Method of Transportation	1925				1926									
	November		December		January		February		March		April		May	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	13850	65.80	7725	$ 36.56	4175	$ 19.95	10100	$ 47.97	24390	$ 115.90	30300	$ 125.00	24000	$110.00
FRT.:														
Pgh.*	13850	65.80	7725	36.56	4175	19.95	10100	47.97	24390	115.90	30300	125.00	24000	110.00
Miss.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Tex.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Tenn.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Ind.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
BOAT	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
EXP.	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------

*Wholesale market.

TABLE 5.—Receipts of Lettuce in Wheeling by Freight and Express: Origin of Shipment, Quantity, and Carrying Charges by Months, June, 1925, to May, 1926, Inclusive

Method of Transportation, and Origin of Shipment by Freight	Total		1925									
			June		July		August		September		October	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	1122098	$12210.37	24260	$ 115.17	20100	$ 95.47	32955	$ 156.27	39595	$ 188.57	51415	$ 244.15
FREIGHT:												
Pittsburgh*	446640	2121.53	24260	115.17	20100	95.47	32955	156.27	39595	188.57	51415	244.15
California	347200	6559.65	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Ohio	92974	297.68	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Arizona	88800	1699.16	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
EXPRESS	146484	1532.37	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------

Method of Transportation	1925				1926									
	November		December		January		February		March		April		May	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	120540	$1549.60	73005	$ 608.69	131898	$1718.03	128166	$1684.02	258361	$2768.35	139110	$1663.20	102693	$1418.85
FRT.:														
Pgh.*	44600	212.32	52125	247.47	27300	129.67	40010	190.00	37140	176.22	37140	176.22	40000	190.00
Cal.	66640	1264.58	20880	361.22	40160	719.68	80960	1452.04	89920	1703.93	24320	491.19	24320	566.99
Ohio	9300	72.70	-------	-------	24278	149.00	7196	41.98	52200	34.00	-------	-------	-------	-------
Ariz.	-------	-------	-------	-------	40160	719.68	-------	-------	-------	-------	24320	456.74	24320	522.74
EXP.	-------	-------	-------	-------	-------	-------	-------	-------	79101	854.20	53330	539.05	14053	139.12

*Wholesale market.

pally from Ohio. Freight shipments came from Ohio, California, and Arizona, with many small shipments from Pittsburgh which in all probability were California and Arizona lettuce. The average carrying charge for the total receipts was $1.09 per cwt., while the average carrying charge for the California shipments was $1.88 per cwt. This high carrying charge gives local producers a considerable margin over their competitors in California and Arizona. Some leaf lettuce is grown locally, but no great success in growing head lettuce has been experienced. Consumers seem to prefer head lettuce to the leaf lettuce varieties, and for this reason local producers may not be able to meet competition from California and Arizona.

Miscellaneous Vegetables

Table 6 shows the receipts of miscellaneous vegetables on the Wheeling market. Included are such vegetables as peppers, cucumbers, celery, green beans, and green corn. The larger part of these shipments came from the wholesale markets of Pittsburgh and Columbus.

Poultry and Eggs

Table 7 shows the express receipts of poultry on the Wheeling market. Some poultry was brought to Wheeling by boat, but the records were not sufficient to permit of even a reliable estimate. No shipments came by freight. The 225,331 pounds of poultry came from points in Ohio and West Virginia, no shipments being noted from other states.

Table 8 shows that 20,866 cases of eggs were received on the Wheeling market by freight, boat, and express. The shipments by boat and express came from points in Ohio and West Virginia. The record would indicate that local demands are reasonably well met by local production, yet with some opportunity for expansion of the industry.

Dairy Products

Dairy farming in the Wheeling area in the past two years has met with reverses, and much dissatisfaction and controversy has developed on the part of the dairy farmers. A few years ago there was considerable expansion in the production of market milk in Ohio County. There is nothing to indicate that this was not a healthy expansion, prompted by the demand for fluid milk. Within the last few

TABLE 6.—Receipts of Miscellaneous Vegetables† in Wheeling by Freight and Express: Origin of Shipment, Quantity, and Carrying Charges by Months, June, 1925, to May, 1926, Inclusive

Month	Total		Origin of Shipment by Freight						Express	
			Pittsburgh*		California		Virginia			
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	2694139	14831.84	2110903	$8443.44	22160	$ 468.37	45140	$ 340.00	515936	$5580.03
1925										
June	337869	$1753.85	280135	1129.80	-------	-------	-------	-------	57734	633.05
July	259033	1506.43	186600	746.40	-------	-------	-------	-------	72433	760.03
August	76371	599.73	41365	165.44	-------	-------	-------	-------	35006	434.29
September	113099	654.41	89075	356.40	-------	-------	-------	-------	24024	298.01
October	169839	1315.60	111985	447.60	-------	-------	-------	-------	57854	868.00
November	187689	873.56	104450	418.00	-------	-------	-------	-------	83237	455.56
December	290127	2120.18	159060	636.00	22160	468.37	45140	340.00	63767	675.81
1926										
January	202299	1154.32	166800	667.20	-------	-------	-------	-------	35499	487.12
February	206448	876.25	189503	758.00	-------	-------	-------	-------	16945	171.75
March	207575	929.75	200930	803.60	-------	-------	-------	-------	6645	72.65
April	338515	1550.50	310000	1240.00	-------	-------	-------	-------	28515	310.50
May	305275	1497.26	271000	1084.00	-------	-------	-------	-------	34275	413.26

†Peppers, Cucumbers, Beans, Corn and Celery. *Wholesale market.

Dairy farming holds the place of first importance in the Wheeling area.

TABLE 7.—Receipts of Poultry in Wheeling by Express: Quantity and Carrying Charges, June, 1925, to May, 1926, Inclusive

Month	Quantity in Pounds	Carrying Charges
Total	225331	$2581.56
1925		
June	13862	185.28
July	12996	161.00
August	11343	131.22
September	12938	145.41
October	21852	211.24
November	26307	244.34
December	23511	218.40
1926		
January	11353	108.81
February	15748	152.00
March	26936	377.61
April	27735	373.91
May	19750	272.34

years, however, there has been a surplus of fluid milk on the market. This has come about because of an extension of the highway system which has made it possible for many farmers to bring milk to Wheeling from points in Ohio and West Virginia as much as fifty miles away. The fluid-milk producing area has been widely extended. Land values are not nearly so high outside of the suburban area of Wheeling and across the Ohio River on the Ohio side. Dairy farmers in Ohio County are finding it almost impossible to compete with those on cheaper land. The surplus milk must go into manufactured products, or find a market elsewhere. It is questionable if Ohio County dairymen can compete with cheap land areas in producing milk for manufactured products.

Cost of Producing Milk

Data were collected from ten dairy farmers in Ohio County in May, 1926, showing their estimated cost of producing dairy products. The survey method was used in collecting the data. All the costs of producing milk were included, such as costs of feed, labor, depreciation on cows and buildings, taxes, equipment, repairs, and service fees. The value of manure, calves produced, and service fees was deducted from these costs.

The herds numbered from twelve to twenty-two cows and the dairymen were considerably better than the average dairymen of the county.

Costs of milk production ranged from 20.1c to 42.5c per gallon, with an average of 29.8c for the ten producers. At this time these

TABLE 8.—Receipts of Eggs in Wheeling by Freight, Express, and Boat: Origin of Shipment, Quantity, and Carrying Charges by Months, June, 1925, to May, 1926, Inclusive

Month	Origin of Shipment by Freight					
	Total		Chicago*		Iowa	
	Cases	Carrying Charges	Cases	Carrying Charges	Cases	Carrying Charges
Total	20866	$7546.80	6021	$2089.85	2000	$ 725.02
1925						
June	2171	712.51	254	113.30	------	------
July	1162	499.87	655	267.58	------	------
August	1807	751.87	1205	479.08	------	------
September	844	312.36	------	------	400	125.08
October	2186	715.62	1232	372.17	400	122.96
November	3355	1106.90	1645	434.43	800	365.68
December	1242	552.44	565	216.71	------	------
1926						
January	1814	676.53	215	94.58	400	111.30
February	1998	351.39	250	112.00	------	------
March	2276	914.17	------	------	------	------
April	1170	506.75	------	------	------	------
May	841	446.39	------	------	------	------

Month	Origin of Shipment by Freight				Express		Boat	
	Ohio		Miscellaneous					
	Cases	Carrying Charges	Cases	Carrying Charges	Cases	Carrying Charges	Cases	Carrying Charges
Total	3130	$ 728.26	105	$ 25.82	9346	$3907.15	264	$ 70.70
1925								
June	1390	335.89	9	2.43	518	260.89	------	------
July	85	21.63	------	------	422	210.66	------	------
August	58	14.75	------	------	534	255.84	10	2.20
September	86	23.15	------	------	349	162.15	9	1.98
October	210	56.55	------	------	333	161.24	11	2.70
November	475	82.72	------	------	426	219.57	9	4.50
December	40	11.45	------	------	624	317.78	13	6.50
1926								
January	400	75.47	25	8.00	774	387.18	------	------
February	------	------	50	10.94	1692	227.13	3	1.32
March	234	63.25	------	------	1862	805.92	180	45.00
April	152	43.40	12	3 16	980	453.69	26	6.50
May	------	------	9	1.29	832	445.10	------	------

*Wholesale market.

producers were selling whole milk at from 25c to 60c per gallon. Other producers were selling whole milk at as low as 20c per gallon wholesale. None of the ten producers interviewed was losing money on his milk; some were making but small margins of profit; others were making fairly satisfactory profits. With the volume of business involved, the margin of profit on milk was not sufficient for the most economical producers to make more than fairly good wages.

Table 9 shows the receipts of condensed milk on the Wheeling market.

Table 10 shows the receipts of cheese on the Wheeling market.

Table 11 shows the receipts of oleomargarine on the Wheeling market.

TABLE 9.—Receipts of Condensed Milk in Wheeling by Freight: Quantity and Carrying Charges by Months, June, 1925, to May, 1926, Inclusive

Month	Quantity in Pounds	Carrying Charges
Total	1759227	$5945.71
1925		
June	189522	751.38
July	443668	1367.83
August	70196	165.27
September	118629	332.24
October	98773	377.22
November	86456	337.61
December	123226	345.31
1926		
January	210280	662.20
February	165742	597.74
March	81479	280.31
April	91346	382.69
May	79910	345.91

TABLE 10.—Receipts of Cheese in Wheeling by Freight and Express: Quantity and Carrying Charges by Months, June, 1925, to May, 1926, Inclusive

Month	Quantity in Pounds	Carrying Charges
Total	1903649	$15912.60
1925		
June	148112	1341.38
July	203810	1985.00
August	213266	1035.47
September	146205	1442.81
October	239171	2070.67
November	127057	1116.08
December	147119	1351.48
1926		
January	131510	1139.30
February	172734	1191.50
March	170868	1516.55
April	102842	946.27
May	100055	726.09

TABLE 11.—Receipts of Oleomargarine in Wheeling by Freight and Express: Quantity and Carrying Charges by Months, June, 1925, to May, 1926, Inclusive

Month	Quantity in Pounds	Carrying Charges
Total	976508	$7537.03
1925		
June	55775	507.15
July	73650	572.42
August	102473	829.70
September	76614	657.85
October	77262	527.80
November	92161	532.11
December	86226	571.13
1926		
January	103688	845.15
February	88398	625.29
March	57357	502.81
April	82263	694.39
May	77641	630.23

Fruits

Peaches

Table 12 shows the receipts of peaches on the Wheeling market.

Apples

Table 13 shows the receipts of approximately 125,000 bushels of apples on the Wheeling market. New York ranks first in terms of quantity shipped, with Ohio second and West Virginia third. The average carrying charges were 37c per cwt. for New York apples, 22c per cwt. for Ohio, and 19c per cwt. for West Virginia, while for Washington apples charges averaged $1.66 per cwt.

Packing apples for the local market.

TABLE 12.—Receipts of Peaches in Wheeling by Freight: Origin of Shipment, Quantity, and Carrying Charges by Months, June, 1925, to May, 1926, Inclusive*

Origin of Shipment	Total		1925			
			June		July	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	2181587	$28080.54	180000	$2624.36	700000	$10332.40
Georgia	920300	13595.56	180000	2624.36	700000	10332.40
North Carolina	80000	1152.50	------	------	------	------
Delaware	27800	485.29	------	------	------	------
California	104109	2545.08	------	------	------	------
New Jersey	181839	1717.91	------	------	------	------
Arkansas	20571	350.61	------	------	------	------
Tennessee	180000	1962.95	------	------	------	------
New York	354992	3296.24	------	------	------	------
Ohio	312276	2974.40	------	------	------	------

Origin of Shipment	1925					
	August		September		October	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	529619	$7443.03	652009	$6471.34	119959	$1209.41
Georgia	40000	638.80	------	------	------	------
North Carolina	80000	1152.50	------	------	------	------
Delaware	27800	485.29	------	------	------	------
California	78073	1787.07	26036	758.01	------	------
New Jersey	103175	1065.81	78664	652.10	------	------
Arkansas	20571	350.61	------	------	------	------
Tennessee	180000	1962.95	------	------	------	------
New York	------	------	333308	3080.98	21384	215.26
Ohio	------	------	213701	1980.25	98575	994.15

*No receipts in months of November, 1925, to May, 1926.

Grapes

Table 14 shows the receipts of 3,747,822 pounds of grapes, with carrying charges amounting to $69,294.44. The larger part of these shipments came from California.

Reports from local farmers indicate that grapes do quite well in this area, and if the preference for the California varieties is not too strong, there seems to be an opportunity for profitable grape culture in this section. California grapes compete with locally-grown and New York grapes during September and October.

Melons

From Table 15 it may be noted that local melon production does not meet the demand even in the height of the local season. In Sep-

TABLE 13.—Receipts of Apples in Wheeling by Freight, Boat, and Express: Origin of Shipment, Quantity, and Carrying Charges by Months, June, 1925, to May, 1926, Inclusive

Method of Transportation, and Origin of Shipment by Freight	Total		1925									
			June		July		August		September		October	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	7462639	35012.12	135835	$ 542.80	147699	$ 879.00	169172	$ 754.32	496870	$1868.08	1322021	$8962.59
FREIGHT:												
Oregon	181422	1202.49	------	------	------	------	------	------	------	------	------	------
Pittsburgh*	1146424	3905.10	135835	542.80	28900	115.40	88200	$201.30	85700	342.80	103165	412.80
Delaware	317440	1470.60	------	------	72000	471.90	24000	152.20	24000	97.20	51840	176.26
Illinois	74150	489.40	------	------	28500	175.40	45650	314.00	------	------	------	------
New York	3096187	9512.39	------	------	------	------	------	------	297370	998.40	494141	1585.39
Ohio	873385	1931.37	------	------	------	------	------	------	26400	166.72	104045	285.26
Maryland	176960	604.03	------	------	------	------	------	------	57120	209.23	24000	97.20
Washington	413513	6873.41	------	------	------	------	------	------	------	------	187110	3210.03
Michigan	78000	325.90	------	------	------	------	------	------	------	------	30000	130.30
West Virginia	517819	974.61	------	------	------	------	------	------	------	------	103520	172.52
Virginia	32160	130.25	------	------	------	------	------	------	------	------	32160	130.25
Idaho	456223	7024.00	------	------	------	------	------	------	------	------	181843	2732.68
Missouri	30315	222.82	------	------	------	------	------	------	------	------	------	------
EXPRESS	23781	216.05	------	------	10199	89.30	9222	79.42	4360	47.33	------	------
BOAT	44860	129.70	------	------	8100	27.00	2100	7.40	1920	6.40	10200	30.00

Method of Transportation	1925				1926									
	November		December		January		February		March		April		May	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	1175518	$4791.48	566721	$2681.73	485477	$2618.55	1008851	$5208.21	846475	$2905.78	610615	$2220.39	497382	$1779.09
FREIGHT:														
Oregon	------	------	------	------	--------	--------	144000	567.60	------	------	------	------	------	------
Pittsburgh*	127650	368.20	212689	475.00	90065	360.00	153500	613.60	99960	390.00	------	------	20760	8320
Delaware	25600	87.04	------	------	------	------	120000	486.00	------	------	------	------	------	------
Illinois	------	------	------	------	------	------	------	------	------	------	------	------	------	------
New York	602727	1681.81	238787	654.19	46800	156.20	210720	735.68	465942	1416.71	348500	1531.50	391200	752.51
Ohio	59600	171.00	------	------	154560	293.56	117260	232.94	206720	392.77	204800	389.12	------	------
Maryland	------	------	24000	74.40	48000	148.80	23840	74.40	------	------	------	------	------	------
Washington	38462	503.85	------	------	------	------	111266	1860.05	39253	625.70	------	------	37422	673.78
Michigan	48000	195.60	------	------	------	------	------	------	------	------	------	------	------	------
West Va.	169349	365.15	------	------	48000	73.20	97950	161.99	24000	55.20	27000	76.95	48000	69.60
Virginia	------	------	------	------	------	------	------	------	------	------	------	------	------	------
Idaho	92190	1385.33	91245	1478.14	60630	951.90	30315	475.95	------	------	------	------	------	------
Missouri	------	------	------	------	------	------	------	------	------	------	30315	222.82	------	------
EXPRESS	------	------	------	------	------	------	------	------	------	------	------	------	------	------
BOAT	11940	33.50	------	------	------	------	------	------	10600	25.40	------	------	------	------

*Wholesale market.

TABLE 14.—Receipts of Grapes in Wheeling by Freight: Origin of Shipment, Quantity, and Carrying Charges by Months, June, 1925, to May, 1926, Inclusive†

Month	Total		Origin of Shipment					
			Pittsburgh*		California		New York	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	3747822	$69294.44	160600	$ 762.83	3099997	$65046.87	487225	$3484.74
1925								
July	40535	624.61	14075	66.85	26460	557.76	------	------
Aug.	201284	3562.67	42275	200.80	159009	3361.87	------	------
Sept.	817683	14861.98	95100	451.72	660768	13882.79	61820	527.47
Oct.	1532222	27436.61	9150	43.46	1209087	25182.40	313985	2210.75
Nov.	1043233	20331.12	------	------	931813	19584.60	111420	746.52
Dec.	112860	2477.45	------	------	112860	2477.45	------	------

*Wholesale market.
†No receipts in months of June, 1925, and January to May, 1926.

TABLE 15.—Melon Receipts in Wheeling by Freight: Origin of Shipment, Quantity and Carrying Charges by months, June, 1925, to May, 1926, Inclusive*

Origin of Shipment	Total		1925	
			June	
	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	4084200	$25748.30	363000	$2498.89
Florida	391600	2827.04	82500	605.27
Georgia	2982400	18948.62	280500	1893.62
Alabama	56500	381.32	------	------
South Carolina	361500	2123.59	------	------
Indiana	208700	1098.81	------	------
Virginia	25200	157.20	------	------
West Virginia	25200	52.92	------	------
Delaware	33100	158.80	------	------

Origin of Shipment	1925					
	July		August		September	
	Pounds	Carrying Charges	Pounds	Carrying Charges	Pounds	Carrying Charges
Total	1974700	$12924.17	1527400	$9221.28	219100	$1103.96
Florida	309100	2221.77	------	------	------	------
Georgia	1425400	9257.80	1215500	7431.40	61000	365.80
Alabama	56500	381.32	------	------	------	------
South Carolina	159700	933.43	201800	1185.11	------	------
Indiana	24000	124.80	84900	447.57	99800	526.44
Virginia	------	------	25200	157.20	------	------
West Virginia	------	------	------	------	25200	52.92
Delaware	------	------	------	------	33100	158.80

*No receipts in months of October, 1925, to May, 1926.

tember 219100 pounds of melons were shipped to the Wheeling market. Only about one eighth of these came from West Virginia, and none from Ohio.

Meat

Table 16 shows the receipts of meat on the Wheeling market. The greater part came from Chicago, Columbus, and Pittsburgh. There is a fair-sized packing plant in Wheeling, as may be judged from receipts of cattle as shown in Table 17 and of hogs as shown in Table 18.

TABLE 16.—Receipts of Meats in Wheeling by Freight: Quantity and Carrying Charges by Months, June, 1925, to May, 1926, Inclusive

Month	Quantity in Pounds	Carrying Charges
Total	15047566	$81818.59
1925		
June	1317856	6877.52
July	1376390	7663.99
August	1526064	7933.30
September	1131709	6221.75
October	1387281	7304.35
November	1187598	6105.31
December	1210118	6372.30
1926		
January	1348239	7476.93
February	1282689	7186.03
March	1419670	7588.62
April	841809	5231.21
May	1018053	5857.28

TABLE 17.—Receipts of Cattle in Wheeling by Freight and Express: Quantity and Carrying Charges by Months, June, 1925, to May, 1926, Inclusive

Month	Quantity in Pounds	Carrying Charges
Total	15396301	$70990.36
1925		
June	603839	2928.07
July	974998	3705.61
August	977574	4363.43
September	1159863	4715.88
October	612116	6160.02
November	1089181	3468.89
December	1320712	5539.59
1926		8614.95
January	1764133	
February	1831322	8156.93
March	2216463	10540.77
April	1387379	6090.49
May	1458721	6705.73

Grain and Mill Feed

Table 19 shows the receipts of grain and mill feed received on the Wheeling market. The Wheeling area is not well adapted to grain production, topography and price of land considered. It is probably more economical for dairymen to buy the bulk of their feed than to attempt to raise it on high-priced land and with high-priced labor.

TABLE 18.—Receipts of Hogs in Wheeling by Freight: Quantity and Carrying and Feed Charges by Months, June 1925, to May, 1926, Inclusive

Month	Quantity in Pounds	Carrying Charges
Total	65635945	$302630.99
1925		
June	7367970	57136.45
July	6103950	38793.97
August	5227081	19984.98
September	5971657	21755.83
October	5474900	19536.27
November	5413470	19430.68
December	5483951	19951.12
1926		
January	5846279	22196.36
February	4698662	18556.87
March	5238306	22428.77
April	4660760	22020.71
May	4148959	20838.98

TABLE 19.—Receipts of Grain and Mill Feed in Wheeling by Freight: Quantity and Carrying Charges by Months, June, 1925, to May, 1926, Inclusive

Month	Quantity in Pounds	Carrying Charges
Total	8777833	$15658.11
1925		
June	600263	1130.73
July	594525	962.15
August	1331009	2616.51
September	849988	1498.45
October	178868	272.24
November	1097426	2042.65
December	974568	1520.24
1926		
January	881899	1471.00
February	497212	905.02
March	630315	1264.65
April	422055	662.83
May	719705	1311.64

SUMMARY

Records of freight, express, and boat receipts show that food commodities are coming to the Wheeling market in large quantities, from distant points and with high freight costs.

Approximately 316,000 bushels of potatoes were brought to the Wheeling market by boat, express, and freight. West Virginia farmers supplied only 1.4 percent of this total and only 3.7 percent of the potatoes received during the four-months' period, August, September, October, and November, which is the peak of the marketing season for locally grown potatoes. The average carrying charges on the potatoes received on the market amounted to 50c per cwt., while for those potatoes coming from West Virginia the carrying charges amounted to 28c per cwt. Prices are favorable for locally grown potatoes.

West Virginia potato growers have scarcely touched the Wheeling potato market. It would seem advisable that steps be taken to open this market for state-grown potatoes.

Large quantities of onions, cabbage, and lettuce came on the market. The market is available but not enough data were collected in this study to hazard advice on the profitableness of the culture of these vegetables locally.

The data show that local production of beans and tomatoes fairly well supplies the market demands for these vegetables during the local producing season.

Poultry production for the local market could stand some expansion before local demands are satisfied.

It would appear that the culture of grapes and small fruits might well take a place on some farms in the area.

While orcharding appears to be over-expanded in the country as a whole, there seems to be an opportunity for farmers in the northern panhandle section to produce apples at a fair profit for local markets.

DISCUSSION

Data on agricultural production costs in the Wheeling area together with comparative costs in the main competing areas are essential in guiding readjustments. A cooperative study by Ohio, Pennsylvania, and West Virginia would be necessary to obtain these data. The present study has gone no further than to point out some of the possibilities of readjustments. It should point the way to more detailed studies of the possibilities for producing locally the various crops for which the local market shows an unfilled demand.

Farmers in the Wheeling area have an advantage in transportation costs because of nearness to market. Yet further study might show that increased production costs would wipe out this advantage in the case of some or all of the commodities considered.

Truck farming appears to be losing in favor in the area, but no definite reason for this circumstance was ascertained.

Dairy farming for market milk production appears to be overdeveloped. If dairymen find that they cannot produce milk for sale at the price of manufactured milk, they may find it profitable to change to other sorts of production. The road system has opened up a large section of cheaper land than is to be found in Ohio County. Consequently more and more of the fluid milk is becoming surplus milk and has to go at manufactured-milk prices.

Dairy farmers in the Wheeling area are in need of a thorough study of milk production and marketing.

Much cabbage is grown for the local market.

Bulletin 229 March, 1930

Cream Line Studies of Market Milk

by G. MALCOLM TROUT

Figure 1.—Cream Line on Milk Held (left to right) at 35° F., 32° F., and 70° F.

UNIVERSITY OF ARIZONA
LIBRARY

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

AGRICULTURAL EXPERIMENT STATION STAFF

JOHN R. TURNER, Ph. D., LL. D. ..... President of the University
F. D. FROMME, Ph. D. ..... Dean and Director
GERALD JENNY, M. S. ..... Agricultural Editor
JOHN C. JOHNSTON ..... Chief Clerk

AGRONOMY AND GENETICS
- R. J. Garber, Ph. D. — Agronomist and Geneticist
- E. P. Deatrick, Ph. D. — Associate Agronomist
- W. H. Pierre, Ph. D. — Associate Agronomist
- T. C. McIlvaine, Ph. D.† — Assistant Agronomist
- D. R. Dodd, B. S.,‡ — Assistant Agronomist
- M. M. Hoover, M. S. — Assistant Agronomist
- H. K. Rowley, M. S. Agr.** — Seed Analyst

ANIMAL HUSBANDRY
- E. A. Livesay, D. Sc. — Animal Husbandman
- Chas. V. Wilson, M. S. — Assistant Animal Husbandman
- J. H. Longwell, M. A. — Assistant Animal Husbandman
- J. H. Rietz, D. V. M. — Associate Veterinarian
- R. H. Tuckwiller, B. S. Agr.* — Assistant Animal Husbandman
- R. S. Glasscock, M. S.** — Assistant in Veterinary Science

CHEMISTRY
- R. B. Dustman, Ph. D. — Agricultural Chemist
- Chas. E. Weakley, Jr., B. A. — Assistant Chemist
- L. P. Hansen, Ph. D. — Assistant Chemist
- T. B. Leith, M. S.** — Assistant Chemist
- Leland Shriver, B. S. Ch. E. — Assistant in Agricultural Chemistry

DAIRY HUSBANDRY
- H. O. Henderson, Ph. D. — Dairy Husbandman
- L. M. Thurston, Ph. D. — Assistant Dairy Husbandman
- K. S. Morrow, M. S. — Assistant Dairy Husbandman
- L. F. Sutton, B. S. Agr.‡ — Assistant Dairy Husbandman

ENTOMOLOGY
- L. M. Peairs, Ph. D. — Entomologist
- W. E. Rumsey, B. S.** — State Entomologist
- Edwin Gould, B. S. Agr. — Assistant in Entomology

FARM ECONOMICS
- A. J. Dadisman, Ph. D. — Farm Economist
- F. D. Cornell, Jr., M. S. — Assistant Farm Mechanician
- W. W. Armentrout, M. S. — Assistant Farm Economist
- R. O. Stelzer, B. S. — Assistant in Farm Economics

HOME ECONOMICS
- Rachel H. Colwell, M. A. — Home Economist
- Hazel C. Cameron, M. A. — Research Specialist in Nutrition

HORTICULTURE
- H. E. Knowlton, Ph. D. — Horticulturist
- K. C. Westover, M. S. Agr. — Assistant Horticulturist
- F. W. Craig, M. S. Agr.** — Assistant Horticulturist
- M. B. Hoffman, M. S. — Assistant in Horticulture
- W. N. McCubbin, M. A. — Assistant in Horticulture
- A. P. Dye, M. S. Agr. — Assistant in Horticulture

PLANT PATHOLOGY
- C. R. Orton, Ph. D. — Plant Pathologist
- Anthony Berg, M. S. — Associate Plant Pathologist
- L. H. Leonian, Ph. D. — Associate Plant Pathologist
- F. J. Schneiderhan, M. S. — Associate Plant Pathologist
- E. C. Sherwood, M. S. — Assistant Plant Pathologist

POULTRY HUSBANDRY
- Horace Atwood, M. S. Agr. — Poultry Husbandman
- T. B. Clark, B. S. Agr. — Assistant in Poultry Husbandry

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-Station, Lakin, W. Va.
‡Resigned, February, 1930.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

Cream Line Studies of Market Milk[*]

by G. MALCOLM TROUT[†]

MARKET milk is judged by the consumer according to its flavor and to the amount of cream appearing in the neck of the bottle.

The fact that butterfat is lighter than milk serum and rises to the top in the form of a cream layer is common knowledge. It is therefore difficult in the event of a small cream layer to explain to the housewife why not all the fat originally present in the milk has risen to the top of the bottle.

The common practice today in the market milk plants is to pasteurize the milk at 140° to 145°F. and to hold it at that temperature for 30 minutes. Then it is pumped over a surface cooler and cooled to below 50°. Such procedure when followed by a skilled operator rarely has a harmful effect upon the flavor, but often does affect the depth of the cream layer. Any methods of procedure that will restore to milk its natural creaming ability or least retard the natural rising of the cream should be of especial value to the market milk industry.

The growing importance of the market milk industry in West Virginia, together with the introduction of much modern machinery, has prompted a study of the effect of agitation and pumping upon the creaming ability of market milk.

HISTORICAL REVIEW

A number of papers have appeared in recent years on the creaming ability of milk and on the effect of certain milk plant operations on the resulting cream layer of market milk. Some have dealt exclusively with the factor of temperatures used in pasteurization, while others have shown the effect of various methods of pasteurization, agitation, and pumping upon the creaming ability of the milk so treated. Only the papers reporting investigational work on the factors under direct control of the milk plant operator are here considered.

Hammer and Hauser *(1914)* in their study on the "in-the-bottle" method of pasteurization found that "a high pasteurization temperature was unsatisfactory for the method of final package pasteurization because of the decreased creaming ability and pronounced heated flavor of the milk so treated."

When the milk was exposed for a short time at various temperatures an increased creaming ability of the milk so treated was frequently observed; but with exposures which would satisfy the requirements governing bacterial efficiency, such an increase was not observed.

Hammer *(1916)* reported that pasteurization can be so carried out that the decrease in the creaming ability will not be very pronounced. He further concluded

*Submitted for publication September, 1928.
†Resigned October, 1928.

that apparently it was impossible to pasteurize milk properly without decreasing the creaming ability. Agitation of milk at ordinary temperatures did not appreciably decrease the creaming ability of the milk; occasionally, in fact, there was a slight increase.

Kilbourne *(1916)* stated that one of the important factors affecting the volume of cream in bottled milk was the amount of agitation to which the milk was subjected, especially while hot. In those plants where there was most agitation of the milk, and particularly when pumping of the hot milk was practised, the greatest difficulty with the cream line was experienced.

Parker *(1917)* quoted Professor Peter of the Swiss Dairy School in Berne as stating that the rapidity of formation as well as the depth of the cream line increased up to a pasteurizing temperature of 141.8°F. Beyond this point these factors decreased, but even at 145.4° they were greater than in raw milk. Parker concluded that milk should never be pumped after pasteurization on account of recontamination and because, if the pumping is done while the milk is hot, the volume of cream that will rise on it is greatly reduced.

Judkins and Downs *(1918)* found during their studies in processing milk that the reduction in the cream line of vat-pasteurized milk cooled in the vat was 2.9 percent and when cooled over the cooler, 1.5 percent. In the case of in-the-bottle pasteurization there was no apparent reduction in the cream line. They noted that the higher the temperature to which the milk was heated, the greater was the reduction in cream line.

Harding *(1921)* observed that the volume of cream on milk began to decrease measurably when the temperature of pasteurization was raised from 142° to 144°F. As the temperature was increased, the decrease in the volume of cream rapidly become more pronounced; at 145° the decrease amounted to slightly more than 10 percent by volume; at 146° it amounted to 16.6 percent; and at 148° to approximately 40 percent.

Wright *(1923)* after investigating the effect of pasteurization of market milk in the glass-enameled tank and in the bottle, reported that the glass-enameled tank when used with a surface coil cooler gave very satisfactory results as compared with the in-the-bottle method. The rapid cooling gave a larger volume of cream, and the line of demarcation was very distinct. The milk passing last over the cooler gave a smaller volume than did the milk passing first.

Martin and Combs *(1924)* made investigations into the effect of milk plant operations on the amount of cream rising on milk. They found that when milk was cooled in the pasteurizer a considerable loss in cream volume occurred, the extent of the loss depending on the type of pasteurizer and on the amount of agitation to which the milk was subjected. Hot milk subjected to agitation showed a gradual loss in creaming ability which was very small for the first two hours, but after that it amounted to from 20 to 65 percent. Pumping milk while cold had little effect on its creaming ability. The average of seven trials in which hot milk was pumped showed but a small loss.

Whittaker and co-workers *(1925)* found that pasteurization at 145° to 146°F. for 30 minutes reduced the cream volume an average of approximately 8 percent, with considerable variations above and below. As to the agitation of milk during pasteurization they reported that tests conducted to show the effect of agitation during the holding period were not uniform, but that the tendency appeared to be

slightly in favor of holding the milk without agitation during that period. They concluded: "Moderate agitation during the 30-minute holding period apparently had no appreciable effect on the cream volume. Pumping milk at temperatures between 60° and 120° reduced the cream volume to a slight extent in some cases. Pumping raw milk below 60° and pumping pasteurized milk at temperatures between 120° and 140° had practically no effect upon the cream volume. Holding or agitating milk at a temperature of 145° had considerably less effect on the cream volume than at temperatures between 60° and 110°."

PURPOSE OF THE EXPERIMENT, AND METHODS USED

The chief objects in the present experiment were to determine the effect of agitation and pumping of milk upon the resulting cream layer, and to determine the critical temperatures at which pumping had the most harmful effect upon the depth of cream layer appearang at the top of the bottle of milk.

The milk samples used in this experiment were obtained in part from the West Virginia University dairy herd and in part from the commercial milk plant at Morgantown. The University herd at the time of the experiment consisted of the four main dairy breeds; about three-fifths of the herd were Holstein, one-fifth Jersey, and the balance Ayrshire and Guernsey. The herds supplying milk to the local plant were of mixed breeding, the Holstein and Jersey breeds predominating.

The milk received at the West Virginia University dairy was pasteurized in a glass-lined tank at 145°F. for 30 minutes. During pasteurization the milk was agitated by a side paddle-wheel rotating at 431 revolutions per minute. After the pasteurization period was completed, the milk was pumped by a centrifugal pump having a speed of 1,135 revolutions per minute over a tubular surface cooler which cooled the milk to 35°. Precooling the milk in the vat, by circulating water in the jacket surrounding the tank, was begun simultaneously with pumping the milk over the cooler.

Samples were taken of the raw milk after it had been thoroughly mixed; of the pasteurized milk before and after pumping at 145°F.; and of the pasteurized milk pumped at 135°, 125°, 115°, 105°, 90°, and 80°, respectively. Samples were obtained under conditions as nearly comparable to plant practices as possible.

The creaming tests were made in 100 c.c. graduate cylinders of an even diameter. The depth of the column of milk within the cylinders was approximately that of a quart milk bottle. Triplicate samples of each lot of milk were taken, one sample of which was creamed in ice water. Another sample was creamed in the milk cooler at 40°F.; and the third sample was creamed at 70°. Measurements of the depth of the cream layer were recorded in sixteenths of an inch after standing two, four, six, and twenty-four hours.

All fat tests were made by the Babcock butterfat test. Samples of cream for a fat test were obtained by pipetting off the cream layer down to one-fourth inch of the lower limit. Precautions were taken to keep the cylinder in an upright position and free from agitation, thus preserving the distinct cream line. The lower fourth-inch cream layer remaining, together with the upper one-inch of serum, was removed by a suction pump. An absorbent cotton swab was used to remove any cream which may have adhered to the sides of the cylinder. The serum then was shaken vigorously, and a sample taken.

Table 1.—Creaming Efficiency of Raw Milk at Various Temperatures

Trial No.	Percentage of Fat in Milk	Depth of Cream Layer*			Percentage of Fat in Cream			Percentage of Fat in Skimmilk		
		32°F. Ice Water	40°F.	70°F.	32°F. Ice Water	40°F.	70°F.	32°F. Ice Water	40°F.	70°F.
1	3.2	17	18	7	19.0	21.0	20.0	.15	.15	1.30
2	3.0	17	17	8	21.0	19.5	21.5	.27	.20	1.20
5	3.3	18	18	7	21.0	19.0	19.0	.40	.40	1.30
8	3.4	16	20	6	22.0	19.0	21.5	.35	.40	1.35
13	3.3	18	18	7	19.5	18.5	19.0	.45	.50	1.40
16	3.6	18	19	6	18.5	18.0	20.5	.45	.45	1.70
18	3.1	16	19	5	22.5	17.5	18.5	.40	.40	1.80
22	3.4	17	19	6	19.0	19.5	25.0	.45	.40	1.90
25	3.0	18	18	7	17.5	18.0	23.0	.40	.40	1.60
28	3.3	17	19	6	20.0	18.0	20.0	.60	.70	1.90
30	3.2	16	17	6	20.0	20.0	19.5	.45	.55	1.60
34	3.6	17	18	5	20.5	20.5	18.0	.50	.55	1.80
37	3.6	16	18	5	22.5	18.0	21.0	.45	.40	1.80
39	3.6	15	17	5	24.0	21.0	25.5	.70	.80	2.20
Av. 39 Trials	3.30	16.85	18.26	5.98	20.54	19.15	21.05	0.47	0.50	1.66
Odds†		very great	very great		very great	very great		1:6	very great	

*Measurements recorded in sixteenths of an inch.

†In cases where the odds were greater than 9999:1 they have been recorded as "very great."

The samples of milk taken at the commercial plant were obtained from the bulk of the raw milk before and after pumping; after preheating at 85° to 90°F.; after clarification; after pasteurization at 145° for 30 minutes in a coil vat; after pasteurization at 145° for 30 minutes in a glass-lined pasteurizer; and after pumping the pasteurized milk by the use of a single-stage homogenizer without pressure to the cooler.

When photographs were taken, 5 c.c. of a saturated solution of Sudan III in 95 percent alcohol were added to each pint of milk. Sudan III rendered the cream line more distinct and made photography possible by coloring the cream layer a deep orange.

EXPERIMENTAL RESULTS

Effect of Various Temperatures of Creaming Raw Milk upon the Percentage of Fat in the Cream and upon the Completeness of Creaming. To gain an impression of the efficiency of creaming, 39 lots of raw milk of known fat content were creamed at 32°, 40°, and 70°F. Table 1 shows a portion of the data obtained, selected to show the variations encountered as well as the representative results. *(Cf. Figure 1, cover page.)*

The data obtained from creaming raw milk at different temperatures show cream layers varying from 15 to 18 units (sixteenths of an inch) when creamed at 32°F.; from 16 to 20 units when creamed at 40°; and from 4 to 8 units when creamed at 70°, while the fat content of the raw milk ranged from 3.0 to 3.6 percent.

The percentage of fat found in the cream layer obtained from creaming milk at 32°F. varied from 17.5 to 24.0 percent; that creamed at 40° ranged from 17.5 to 21.0 percent; while that creamed at 70° showed a minimum test of 18.0 percent fat and a maximum of 25.5 percent fat.

The variations encountered were greatest in the fat test of the milk serum. The serum of the milk creamed at 32°F. varied from 0.15 to 0.70 percent fat; at 40°, from 0.15 to 0.80 percent; and at 70°, from 1.20 to 2.20 percent fat.

The average for 39 trials showed a slightly greater depth of cream layer when the milk was creamed in air at 40°F. rather than in ice water at 32°. The creaming efficiency, as determined by the amount of fat remaining in the milk serum, however, is in favor of the ice-water temperature. The results obtained show greater concentration of fat in the cream layer creamed in ice water, as compared to that creamed at 40°. Likewise less fat remained in the milk serum creamed in ice water than in the milk serum creamed at 40°.

Delayed creaming was encountered in creaming milk at 70°F. Not until after several hours was the line of demarcation distinct. A microscopical examination revealed a greater percentage of large fat globules present in the cream obtained by creaming the milk at 70°, as compared to the percentage present in cream obtained by creaming at 32°and at 40°.

Effect of Various Temperatures of Creaming Milk, Pasteurized at 145°F. for Thirty Minutes, upon the Percentage of Fat in the Cream and upon the Completeness of Creaming. In order to learn what effect pasteurization of milk at 145°F. for 30 minutes might have upon its creaming ability, data were obtained on 30 lots of milk so treated. A portion of the data obtained, sufficient to show the variations and representative results, is included in Table 2.

The depth of the cream layer rising on the pasteurized milk creamed in ice water varied from 10 to 16 units. When pasteurized milk was creamed at 40°F. the range in depth of cream layer was from 7 to 14, while that creamed at 70° ranged from 5 to 8. The results of 30 trials showed an average depth of cream layer of 13.77 when creamed at ice-water temperatures as compared to 11.37 at 40°, and 6.00 at 70°. Like raw milk, the creaming efficiency of pasteurized milk was greater when creamed at 32° than at 40°.

The variation of percentage of butterfat found in the cream layer rising on pasteurized milk creamed at 32°F. ranged from 18.0 to 25.0 percent, with an average for 30 trials of 21.07 percent. When the milk was creamed at 40° the variations encountered were from 17.5 to 24 percent, with an average of 19.92 percent. When the milk was creamed at 70° the fat test ranged from 14.5 to 27.0 percent and averaged 21.83 percent.

The percentage of fat remaining in the milk serum ranged from 0.40 to 1.70 percent when creamed at 32°F.; from 0.60 to 2.10 percent at 40°; and from 0.90 to 2.00 percent at 70°. The average fat tests of the milk serum creamed at 32°, 40°, and 70° were 0.84, 1.35, and 1.68 percent, respectively. The fat remaining in the serum of pasteurized milk creamed at 32° and at 40° was more than twice that found in the serum of raw milk creamed under similar conditions. Very little difference, in either the depth of cream layer or the percentage of fat remaining in the milk serum, was encountered in pasteurized milk and raw milk when creamed at 70°.

Effect of Various Temperatures of Creaming upon the Completeness of Creaming and upon the Percentage of Fat in Cream Rising on Milk Pasteurized at 145°F. for Thirty Minutes and Pumped at 145°F. The results obtained from creaming 15 samples of milk pasteurized and pumped at 145°F. in ice water show a variation of from 7 to 12 units in the depth of cream layer. When creamed at 40° the same milk showed a variation of from 7 to 11 units in the depth of cream layer. At 70° the cream layer ranged from 4 to 6 units. The average depth of cream obtained by creaming at 32°, 40°, and 70° was 9.00, 10.27, and 5.40, respectively. *(See Table 3.)*

The variations encountered in the percentage of fat in cream obtained at 32°F. were from 18.0 to 24.0 percent, with an average of 20.63 percent. The variations at 40° were from 11.0 to 21.0 percent, with an average of 17.40 percent, while those at 70° ranged from 13.5 to 28.5 percent, with an average of 22.57 percent. The percentages of fat found in the various lots of cream compared to the depth of the cream layer on the same samples show that a more efficient creaming of pumped-pasteurized milk is accomplished in ice-water temperatures rather than at 40°. Not only was the depth of cream layer found greater, but the percentage of fat also was found to be higher when the milk was creamed rapidly at the lower temperature. Although the highest fat test was found in the cream obtained by creaming at 70°, the cream layer had little depth and was quite leathery at the surface.

The fat test of the milk serum seemed to give a more satisfactory indication of the efficiency of creaming, since the efficiency of creaming is calculated from the proportion of fat remaining in the milk serum rather than from the depth of cream appearing on the column of milk. At 32°F. the range of fat remaining in the serum was from 0.90 to 2.00 percent; at 40° the range was from 1.20 to 2.20 percent; and at 70° the variations encountered were from

Table 2.—Creaming Efficiency of Milk Pasteurized at 145°F. for 30 Minutes when Creamed at Various Temperatures

Trial No.	Percentage of Fat in Milk	Depth of Cream Layer*			Percentage of Fat in Cream			Percentage of Fat in Skimmilk		
		32°F. Ice Water	40°F.	70°F.	32°F. Ice Water	40°F.	70°F.	32°F. Ice Water	40°F.	70°F.
1	3.2	12	10	5	19.0	20.0	20.0	.90	1.20	1.40
2	2.9	10	7	5	23.5	18.5	22.5	1.70	2.10	2.00
4	3.3	15	12	6	21.5	21.5	24.5	.65	1.15	1.45
7	3.6	14	11	6	18.0	17.5	20.0	.65	1.40	1.70
11	3.2	16	12	7	23.5	20.0	23.0	.50	1.20	1.50
14	3.4	16	14	8	20.0	19.0	20.5	.40	0.60	0.90
16	3.0	15	12	7	18.0	22.5	23.0	.80	1.25	1.40
20	3.6	14	11	5	20.5	20.0	14.5	.90	1.40	1.80
23	3.5	15	12	5	18.5	20.5	21.0	.80	1.20	1.70
27	3.4	14	12	6	25.0	18.5	21.0	.80	1.40	1.80
30	3.6	14	12	6	23.0	24.0	27.0	1.00	1.60	2.00
Av. 30 Trials	3.32	13.77	11.37	6.00	21.07	19.92	21.83	0.84	1.35	1.68
Odds		very great	very great		1110:1	4999:1		very great	very great	

*Measurements recorded in sixteenths of an inch.

Table 3.—Creaming Efficiency of Pasteurized Milk Pumped at 145°F. when Creamed at Various Temperatures

Trial No.	Percentage of Fat in Milk	Depth of Cream Layer*			Percentage of Fat in Cream			Percentage of Fat in Skimmilk		
		32°F. Ice Water	40°F.	70°F.	32°F. Ice Water	40°F.	70°F.	32°F. Ice Water	40°F.	70°F.
1	3.0	12	10	5	18.0	18.0	15.5	1.25	1.75	1.60
2	3.2	9	8	5	20.0	16.0	19.0	1.40	1.80	1.70
3	3.5	12	10	6	20.0	11.0	25.0	0.90	1.20	1.50
4	3.3	12	10	6	20.0	18.0	28.0	1.20	1.20	1.60
5	3.6	9	8	5	20.0	18.5	21.0	1.80	2.00	2.00
8	3.5	10	9	5	23.0	21.0	23.0	1.70	2.00	2.00
10	3.6	8	7	5	18.0	18.0	24.0	1.80	2.20	1.50
11	3.0	7	7	4	21.0	18.0	13.5	2.00	2.20	2.10
13	3.6	11	10	5	19.5	15.0	21.0	1.00	1.30	1.40
14	3.0	12	10	6	22.5	15.0	24.0	1.30	1.70	1.90
15	3.6	12	11	6	24.0	17.0	28.5	1.00	1.60	1.80
Av. 15 Trials	3.343	9.00	10.27	5.40	20.63	17.40	22.57	1.45	1.73	1.74
Odds		4999:1	very great		587:1	434:1		very great	not significant	

*Measurements recorded in sixteenths of an inch.

Table 4.—Comparison of Creaming Efficiency of Raw, Pasteurized, and Pumped-Pasteurized Milk when Creamed at Various Temperatures

Treatment of Samples	Number of Trials	Average Percent Fat	Storage Temperature	Depth of Cream*	Percent of Total Cream	Percent Fat in Cream	Percent Fat in Skimmilk
Raw	39	3.30	32°F.	16.85	100.	20.54	0.47
			40°F.	18.26	108.	19.15	0.50
			70°F.	5.98	35.	21.05	1.66
Pasteurized at 145°F. for 30 minutes	30	3.32	32°F.	13.77	82.	21.07	0.84
			40°F.	11.37	67.	19.92	1.35
			70°F.	6.00	36.	21.83	1.68
Pasteurized at 145°F. for 30 minutes and pumped at 145°F.	15	3.34	32°F.	10.27	61.	20.63	1.45
			40°F.	9.00	53.	17.40	1.73
			70°F.	5.40	32.	22.57	1.74

*Measurements recorded in sixteenths of an inch.

1.50 to 2.10 percent. The average fat tests in the milk serum of the 32°, 40°, and 70° lots were 1.45, 1.73, and 1.74 percent, respectively.

Comparison of Creaming Efficiency of Raw, Pasteurized, and Pasteurized-pumped Milk at 145°F.

As indicated in Table 4, creaming raw milk at 40°F. gave a greater depth of cream layer after 24 hours than when creamed in ice water for a similar period. However, the percentage of fat in the cream obtained at 40° was less than that in cream obtained at 32°. The efficiency of skimming as shown by the percentage of fat remaining in the milk serum was in favor of creaming at 32°.

Milk which had been pasteurized at 145°F. for 30 minutes gave a greater depth of cream layer at 32° than at 40° and 70°. Not only was the depth of cream greater at this temperature, but the percentage of fat in the cream also was greater by 1.0 percent. When the pasteurized milk was creamed at 32°, approximately one-third less fat remained in the serum than when the milk was creamed at 40°, and one-half less than when the milk was creamed at 70°.

The processing of milk had little effect upon creaming ability when it was creamed at 70°F. The fat test of the milk serum remained practically the same for the various lots, being 1.66, 1.68, and 1.74 percent. A microscopical examination of cream from the various lots obtained at 70° showed a high percentage of large fat globules. Apparently these globules are not prevented from rising to the surface by the practices of processing milk commonly employed in the modern milk plant.

Table 5.—Rate of Creaming and Percentage of Total Cream Rising on Milk Processed Under Various Plant Conditions

Treatment of Samples	Number of Trials	Percent of Fat in Milk	Storage Temperatures °F.	Percentage of Total Cream Rising			
				Held 2 Hrs.	Held 4 Hrs.	Held 6 Hrs.	Held 24 Hrs.
Raw	62	3.72	32	92.2	98.6	100.0	89.3
			40	82.1	84.5	83.1	86.4
			70	30.4	31.0	32.0	35.0
Pasteurized at 145°F. 30 minutes.	62	3.72	32	90.8	92.4	92.3	85.4
			40	79.0	82.4	82.0	84.0
			70	51.3	52.1	53.3	52.0
Pasteurized-pumped at 145°F.	61	3.72	32	91.5	90.2	90.8	83.5
			40	82.8	84.1	81.1	81.7
			70	66.5	64.3	62.0	56.5
Pasteurized-pumped at 135°F. ...	54	3.72	32	93.9	92.5	91.0	83.3
			40	83.1	84.8	83.3	83.0
			70	64.1	60.6	58.9	54.9
Pasteurized pumped at 125°F. ...	58	3.72	32	95.4	93.4	92.4	84.0
			40	85.7	87.4	85.8	83.3
			70	73.5	62.0	60.8	55.5
Pasteurized-pumped at 115°F. ...	56	3.72	32	97.2	95.5	94.2	82.8
			40	85.7	87.9	87.9	83.6
			70	65.5	65.1	62.4	56.0
Pasteurized-pumped at 105°F. ...	32	3.72	32	92.9	90.1	90.4	80.9
			40	95.9	93.6	91.1	82.7
			70	73.9	70.4	68.1	59.3
Pasteurized-pumped at 90°F.	4	3.72	32	94.5	98.3	94.5	82.1
			40	68.4	73.4	74.7	79.6
			70	54.7	53.5	52.2	51.0
Pasteurized-pumped at 80°F.	4	3.72	32	95.8	97.1	97.2	79.6
			40	65.9	74.6	75.9	75.9
			70	58.7	46.0	44.8	46.0

Effect of Pasteurizing, Agitating, and Pumping Milk upon the Percentage of Cream Rising on Milk after Two, Four, Six, and Twenty-four Hours, at Storage Temperatures of 32°, 40°, and 70°F. Table 5 gives a summary of the data obtained by creaming various lots of milk at different temperatures. The maximum amount of cream rising on raw milk was taken as a standard of 100 percent, and all calculations were made from that basis.

Sixty-two trials of creaming raw milk at 32°F. resulted in the rising after two hours of 92.2 percent of the total cream; 98.6 percent after four hours; and the maximum, or 100 percent, after six hours. At the end of the 24-hour period this volume of cream shrank back to 89.3 percent, a loss in depth of cream of 10.7 percent. At 40° the creaming of raw milk was somewhat slower, reaching its maximum depth after 24 hours, when the cream layer was 2.9 percent less than the cream volume appearing on raw milk after 24 hours at 32°. Raw milk creamed very slowly at 70°, but similar to creaming at 40° it increased upon standing until a maximum of 35 percent was reached after 24 hours.

The rate of creaming in pasteurized milk was comparable to that of raw milk, although the volume of cream appearing on the top of the milk was somewhat less. At 32°F. the maximum volume of cream appeared after 6 hours, while at 40° the maximum was not reached until after 24 hours' exposure. At 70° the maximum cream volume was reached after six hours' exposure after which the volume of cream shrank slightly.

Pumping pasteurized milk at 145°F. resulted in very little change in the rate of creaming at 32°, the maximum amount of cream appearing after 6 hours. When creamed at 40° the greatest volume of cream appeared after four hours, while at 70° the greatest depth of cream was present after two hours.

The general results obtained from creaming pasteurized milk pumped at temperatures ranging from 105° to 135°F., inclusive, showed the greatest depth of cream layer after two hours with the 32° exposure, after four hours with the 40° exposure, and after two hours at 70°.

Although the number of trials did not warrant a justifiable conclusion, it appeared from the results of the four trials studied that pumping pasteurized milk at 80° and 90°F. retards the rate of creaming. The greatest depth of cream layer was obtained after an exposure of six hours at both 32° and 40°. When creamed at 70° the greatest depth of cream appeared after two-hour exposure. The cream was similar in this respect to the results obtained from creaming milk pumped at the higher temperatures.

In every case there was a decided shrinkage in the volume of cream appearing on milk creamed at 32°F. between the six-hour and the 24-hour periods. *(See Figure 2.)* In cases where a large volume of cream appeared in a short period of time, the cream was bulky, coarse, and granular. As the exposure lengthened, the cream became more compact and lost its loose rough appearance as a result of the separation of the fat globules from the surface serum, as the globules clumped together. When the milk was creamed at 70° the differences in the depth of the cream layer of the lots of milk for any period of creaming were of little consequence.

Raw milk creamed at 32°F. showed a shrinkage of 10.7 percent in the cream volume between the six-hour and the 24-hour periods. The average shrinkage of milk pasteurized and pasteurized-pumped at temperatures be-

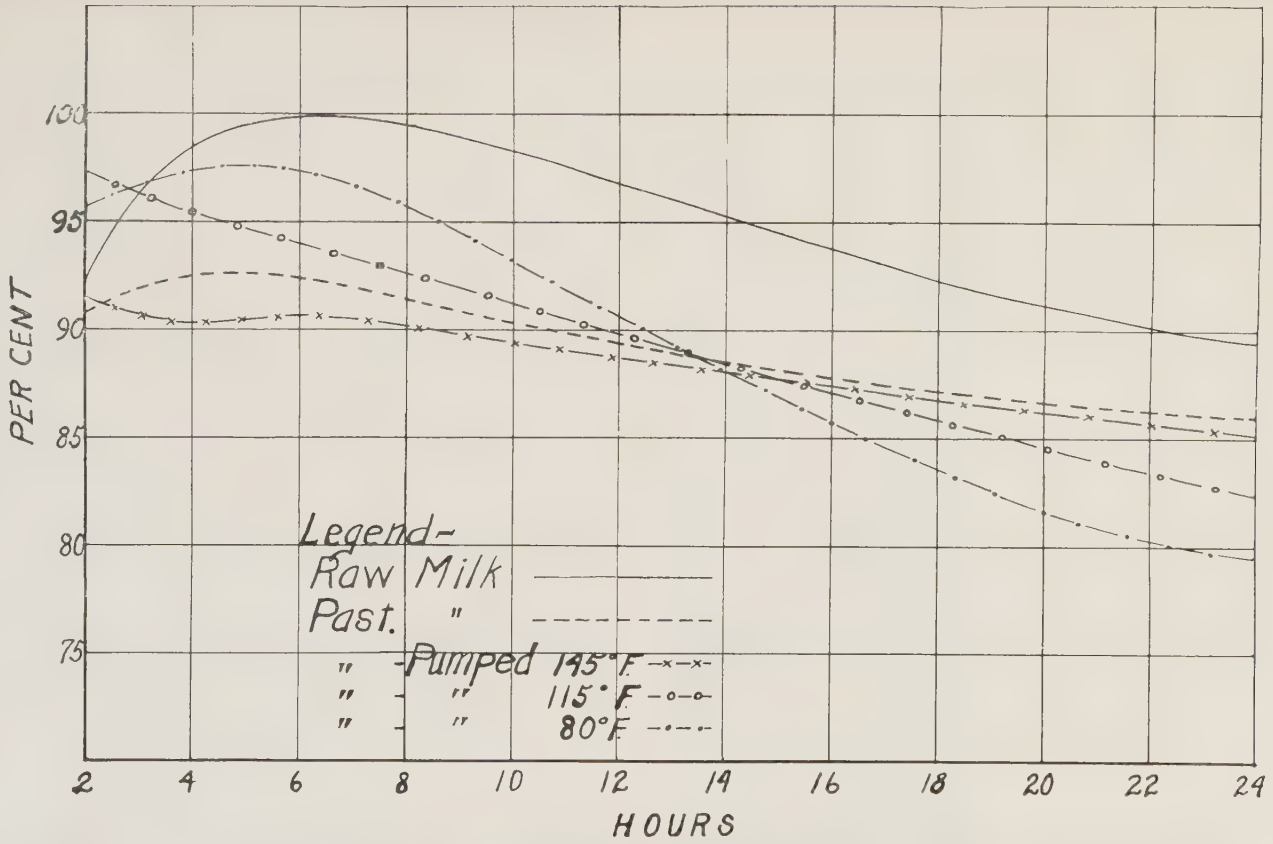


Figure 2.—Chart Showing Percentage of Cream Rising on Milk under Various Plant Conditions When Held at Ice-Water Temperatures for Various Periods of Time

tween 105° and 145° and creamed under the same conditions was only 8.8 percent. The shrinkage encountered when the milk was pasteurized-pumped at 80° to 90°, as shown by the four trials, was 15 percent.

Raw milk creamed at 40°F. showed an increase of 3.3 percent in the depth of cream layer between the six-hour and the 24-hour periods. When pasteurized and pasteurized-pumped at 145° the increase during the same period was slight, whereas there was a slight reduction in the depth of cream layer when the pasteurized milk was pumped at temperatures ranging from 105° to 135° and creamed for 24 hours at 40°.

Effect of Pasteurizing, Agitating, and Pumping upon the Creaming Ability of Milk. In an endeavor to find what effect the processing of milk under modern plant conditions had upon the creaming ability of the milk, a number of samples were taken from the regular lot at the different stages of processing and creamed for 24 hours in ice water, at 40°F., and at 70°. The results of these trials are given in Table 6. All the results were standardized to the equivalent of 4 percent milk.

The depth of cream appearing on raw milk creamed at 32°F. for 24 hours was taken as 100 percent. From this standard all other calculations were made. The results of 92 trials showed that pasteurization at 145° for 30 minutes decreased the depth of cream rising on a column of milk held for 24 hours in ice water by 8.85 percent. Although this reduction in cream layer due to pasteurization is of importance to the milk plant operator, since it challenges higher pasteurization temperatures, it is of little significance to the milk consumer, since, as shown in Figure 3, an 8 percent reduction in cream layer is hardly noticeable.

Table 6.—Depth of Cream Layer Appearing on Milk Processed According to Plant Operations after Twenty-four Hours' Exposure to Various Temperatures

Treatment	Number of Trials	Percent Fat in Milk	Storage Temperatures °F.	Depth of Cream*	Percent of Total Cream
Raw	101	4.0	32	19.50	100.00
			40	19.72	101.10
			70	7.35	37.70
Pasteurized 145°F. 30 min..	92	4.0	32	17.78	91.15
			40	16.63	85.28
			70	9.82	50.37
Pasteurized-pumped 145°F..	70	4.0	32	16.82	86.27
			40	16.34	83.81
			70	11.06	56.71
Pasteurized-pumped 135°F..	55	4.0	32	17.87	91.64
			40	17.70	90.78
			70	11.79	60.44
Pasteurized-pumped 125°F..	58	4.0	32	17.89	91.74
			40	17.74	90.99
			70	11.74	60.18
Pasteurized-pumped 115°F..	57	4.0	32	17.97	92.13
			40	17.80	91.25
			70	12.00	61.55
Pasteurized-pumped 105°F..	32	4.0	32	17.26	88.48
			40	17.61	90.29
			70	12.63	64.77
Pasteurized-pumped 90°F...	4	4.0	32	17.48	89.63
			40	16.95	86.92
			70	10.86	55.68
Pasteurized-pumped 80°F...	4	4.0	32	16.95	86.92
			40	15.92	81.63
			70	9.80	50.25

*Measurements recorded in sixteenths of an inch.

Pumping the pasteurized milk at 145°F. further reduced the cream volume by approximately 5 percent, thereby making a total reduction, due to combined pasteurization and pumping at 145°, of 13.73 percent. This figure represents the greatest loss encountered by pasteurization or by pumping at temperatures ranging from 80° to 145° when the milk was creamed at 32°.

The pumping of pasteurized milk at 135°, 125°, or 115°F. resulted in little change in depth of cream layer from that obtained by pumping pasteurized milk at 145°. Pumping pasteurized milk at these temperatures tends slightly to increase the depth of cream layer. When pasteurized milk was pumped at 105°, 90°, and 80°, respectively, and creamed at 32°, there was a slight reduction in the depth of cream layer but this was not as much as when the pasteurized milk was pumped at 145°.

Figure 3.—Cream Line on Milk Held at 32° F. for 24 Hours under Various Plant Conditions

When samples of the same milk were creamed at 40°F., considerable variations from the results obtained in the ice-water creaming were encountered. Although the cream from raw milk was a little slower in rising at 40° than at 32°, a volume greater by 1 percent was obtained after 24 hours. Pasteurization affected the cream volume by a 15.82 percent reduction, and pumping the pasteurized milk at 145° resulted in a combined loss of 17.29 percent.

A reduction in cream layer averaging 10.3 percent was encountered when milk was pumped at temperatures ranging from 105° to 135°F. and held for 24 hours at 40°. The amount of cream on the milk pumped at these temperatures after 24 hours compared very favorably with that on pasteurized milk creamed at 32° for a similar period. Pumping pasteurized milk at temperatures ranging from 105° to 135° resulted in an average increase of 5.55 percent in the depth of cream layer over that of the pasteurized milk creamed under the same conditions. Pumping pasteurized milk at 80° to 90° and holding at 40° for 24 hours resulted in a reduction of the cream layer of 19.47 and 14.18 percent, respectively. Although these reductions are considerably greater than those encountered when pumping at temperatures between 105° and 135°, they are yet comparable to reductions encountered in pasteurized milk and in pasteurized milk pumped at 145° and creamed at 40°.

When the various lots of milk were creamed at 70°F., the total volume of cream rising on the milk ranged from 37.7 percent in the raw milk to 64.7 percent in the milk pasteurized and pumped at 145°. Pasteurization and pumping of milk increased the creaming ability at room temperatures.

The cream layer is never more than one-third butterfat at best; in fact, the highest percentage of fat encountered in the cream layers studied was but 28.5 percent. The depth of cream layer therefore is determined largely by the amount of non-fat material such as water, milk sugar, or coagulated proteins which the fat globules carry to the surface as they rise through the milk. Heat and agitation tended to render the fat globules free by reducing the viscosity and by making available the non-fat material, principally the proteins, which may readily be carried along with the fat to the surface.

A microscopical examination of the various lots of milk showed significant differences in the size and arrangement of the fat globules. In raw milk the fat globules appeared singly with a preponderance of the larger globules. *(See Figure 4.)* Pasteurization at 145°F. for 30 minutes did not materially decrease the size of the globules or change their arrangement. *(See Figure 5.)* There appeared, however, a tendency for the globules to unite.

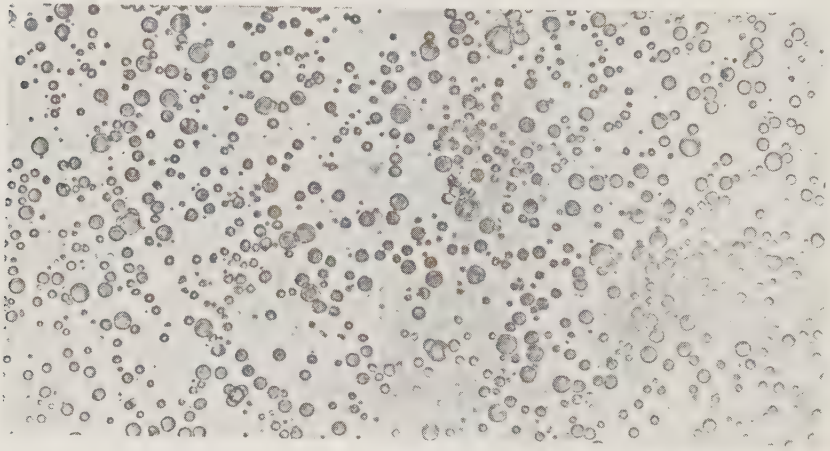


Figure 4.—Fat Globules of Raw Milk

Pumping pasteurized milk at 145°F. caused a slight clumping of the fat globules. *(See Figure 6.)* In some cases the number of clumps predominated over the number of single globules. Furthermore, the size of the globules was smaller on account of the breaking up of the individual globules. At the lower temperatures of pumping, clumping was less pronounced, but the proportion of small fat globules to the large globules increased very materially. *(See Figure 7.)*

The milk was subjected to agitation for an average period of approximately one and one-half hours, depending somewhat upon the amount of milk received for pasteurization. Of this period, from 23 to 26 minutes was required to heat the milk to the pasteurization temperatures; 30 minutes was allowed for the time of pasteurization; and the remainder was required for pumping the milk over the cooler.

When the glass-lined tank was filled with milk the agitation was such that the milk flowed in a steady current about the tank. As the milk was pumped over the cooler, thereby lowering the depth within the tank, the rate

of agitation increased, becoming so violent that considerable splashing and foaming occurred which necessitated turning off the agitator.

Agitation for such a prolonged period of time, together with further agitation through pumping at various temperatures, decreased the cream line never more than 13.73 percent when the milk was creamed at 32°F. Under the same conditions of agitation and pumping, the cream line was decreased 19.47 percent when the creaming temperature was 40°. Of this reduction 15.82 percent is attributed to pasteurization, leaving a loss due to subsequent agitation and pumping of but 3.65 percent. Agitation, as well as pasteurization, increased the creaming ability of milk when the milk was creamed at 70°.

Table 7.—Effect of Preheating, of Clarification, and of Various Types of Pasteurizers upon Depth of Cream Layer

Lot No.	Treatment	No. of Trials	Percent Fat in Milk	Storage Temperature	Depth of Cream*	Percent of Total Cream
1	Raw	23	4.0	32°F.	22.76	100.00
2	Pumped 60-65°F. Preheated 85-90°F....	23	4.0	32°F.	20.84	91.55
3	Lot No. 2 Clarified 85-90°F.....	23	4.0	32°F.	20.84	91.53
4	Lot No. 3 pasteurized at 145°F. 30 minutes in glass-lined tank	8	4.0	32°F.	20.55	86.50
5	Lot No. 4 pumped through homogenizer under no pressure...	8	4.0	32°F.	19.72	83.10
6	Lot No. 3 pasteurized at 145°F. 30 minutes in coil vat	23	4.0	32°F.	19.59	86.04

*Measurements recorded in sixteenths of an inch.

Effect of Pumping and Preheating upon the Creaming Ability of Raw Milk.† In a great many plants the milk is pumped from the receiving room to the pasteurizing room, where it is preheated, clarified, pasteurized, and passed over a cooler to the bottling machine. Several samples of milk were taken of

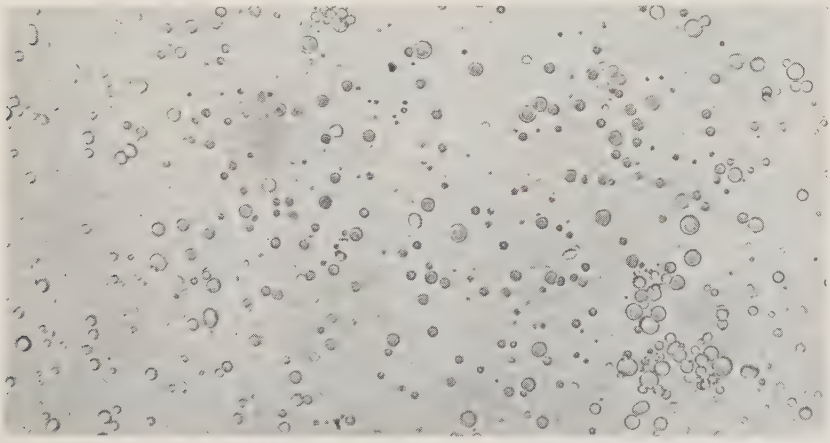


Figure 5.—Fat Globules of Milk Pasteurized at 145° F. for 30 Minutes

†Experiment conducted at commercial plant.

the several operations in such a plant and creamed in ice water to note their effect upon the cream line. The results of these trials are given in Table 7.

When the milk was pumped at temperatures ranging from 60° to 70°F., preheated to 85° to 90°, and creamed at ice-water temperatures, the reduction in the volume of cream rising to the surface amounted to 9.8 percent.

Effect of Clarification upon the Creaming Ability of Milk. Clarification of the preheated milk had little effect on the creaming ability of milk beyond that incurred by preheating. Although the milk was subjected to severe agitation for a brief period of time during clarification, the injury to the cream line

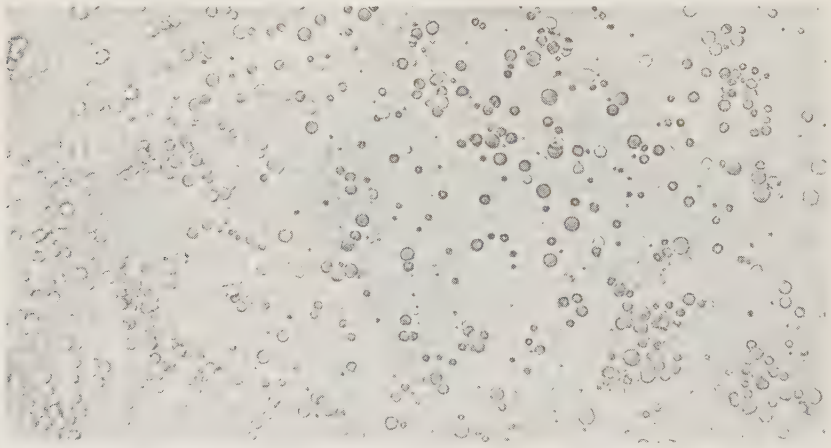


Figure 6.—Fat Globules of Milk Pasteurized and Pumped at 145° F.

resulting therefrom was not sufficient to counterbalance the desirable results. By breaking up the fibrin, by removing a large portion of the leucocytes, and by eliminating all solid foreign material which may have been in the milk in a finely divided state of suspension, the milk was rendered less viscous, thereby permitting the free passage of the fat globules through the milk and thus tending toward a more efficient creaming.

Effect of Various Types of Pasteurizing Vats upon the Resulting Cream Layer when Creaming Milk for Twenty-four Hours at 32°F. After clarification the milk was divided into two lots, one of which was pateurized in a 300-gallon coil-vat pasteurizer at 145°F., while the other was pasteurized under the same conditions in a 200-gallon glass-lined tank similar in design to the one previously described.* The results of these trials show little difference in the volume of cream appearing on the milk pasteurized in either the coil-vat type of pasteurizer or the glass-lined tank pasteurizer. The amount of cream rising on the coil-vat pasteurized milk was but 85.04 percent, whereas in the glass-lined tank pasteurized milk the cream volume was 86.5 percent. The difference in the depth of cream layer as encountered in the two methods of pasteurization was very slight. Such a small difference is not appreciable to the

*See page 5.

eye, yet when the cream layer already is reduced materially by pumping, preheating, clarifying, and pasteurizing, further reductions, even though slight, make an aggregate which is readily perceptible.

Pumping the glass-lined tank pasteurized milk through the single-stage homogenizer without pressure resulted in a further reduction of the cream volume by 3.4 percent.

SUMMARY OF RESULTS

A greater creaming efficiency resulted when milk, raw, pasteurized, or pumped, was creamed in ice-water temperatures than when creamed at higher temperatures in air. Although the depth of cream layer was usually greater in milk creamed in ice water, the volume gradually shrank upon standing, while that creamed at 40°F. gradually increased in depth. The greatest depth of cream layer on raw milk creamed at ice-water temperatures appeared after six hours, while milk creamed at 40° did not yield the maximum depth of cream layer until after 24 hours.

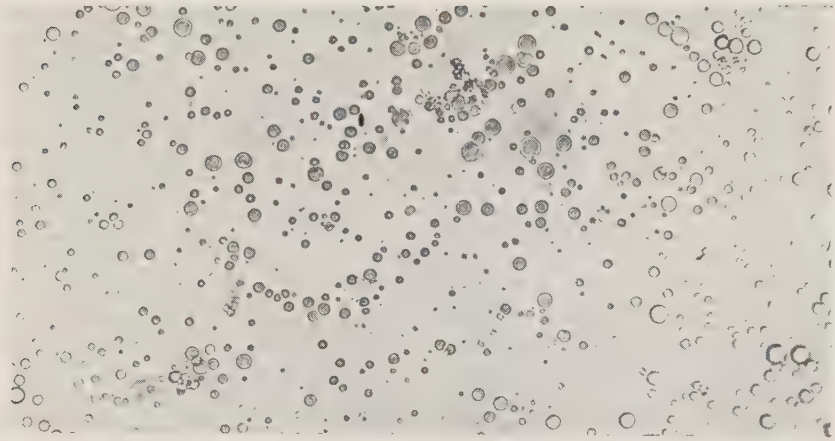


Figure 7.—Fat Globules of Milk Pasteurized and Pumped at 80° F.

Wide variations existed in the percentage of butterfat present in cream obtained by creaming raw and pasteurized milk at different temperatures, although little variation in the average percentage of fat was found in the cream of the one as compared to that of the other. Cream obtained from gravity-creamed raw milk, pasteurized milk, or pasteurized-pumped milk averaged approximately 20 to 22 percent of fat, irrespective of the depth of the cream layer.

Pasteurizing milk at 145°F. for 30 minutes decreased the creaming ability of milk from 9 to 16 percent, depending upon the temperature of creaming. Pumping pasteurized milk at 145° further decreased the creaming ability of the milk from 2 to 5 percent. When the pasteurized milk was pumped at 80° and 90° the creaming ability of milk was decreased to a point comparable to that of pumping pasteurized milk at 145°. Pumping pasteurized milk at temper-

atures between 115° and 135° increased the creaming ability slightly, thereby recovering part of the loss incurred by pasteurization. Pumping pasteurized milk at temperatures between 105° and 145° increased the rate of creaming irrespective of the temperatures at which the milk was creamed. Excessive agitation at temperatures between 105° and 135° did not materially decrease the creaming ability of milk.

Pumping raw milk at 60°F. and preheating to 85° to 90° decreased the creaming ability of milk about 9 percent. Clarification of preheated raw milk had little effect upon the creaming ability of the milk beyond that resulting from pumping and preheating. Pasteurizing pumped clarified milk in a coil-vat pasteurizer, or in a glass-lined pasteurizer, further decreased the cream volume to an approximate total of 14 percent.

LITERATURE CITED

HAMMER, B. W.
1916. STUDIES ON THE CREAMING ABILITY OF MILK. Iowa Agr. Expt. Sta. Research Bul. 31.

HAMMER, B. W., and HAUSER, A. J.
1914. THE PASTEURIZATION OF MILK IN THE FINAL PACKAGE. Iowa Agr. Expt. Sta. Bul. 154.

HARDING, H. A.
1921. EFFECT OF TEMPERATURE OF PASTEURIZATION ON THE CREAMING ABILITY OF MILK. Ill. Agr. Expt. Sta. Bul. 237.

JUDKINS, H. F., and DOWNS, P. A.
1918. STUDIES IN PROCESSING MILK. Conn. (Storrs) Agr. Expt. Sta. Bul. 99.

KELLY, E., and CLEMENT, C. E.
1923. MARKET MILK. New York.

KILBOURNE. H.
1916. THE PASTEURIZATION OF MILK FROM A PRACTICAL VIEWPOINT. New York.

MARTIN, W. H., and COMBS, W. B.
1924. THE EFFECT OF MILK PLANT OPERATIONS ON THE AMOUNT OF CREAM RISING ON MILK. Jour. Dairy Sci. 7:197-204.

PARKER, H. N.
1917. CITY MILK SUPPLY. New York.

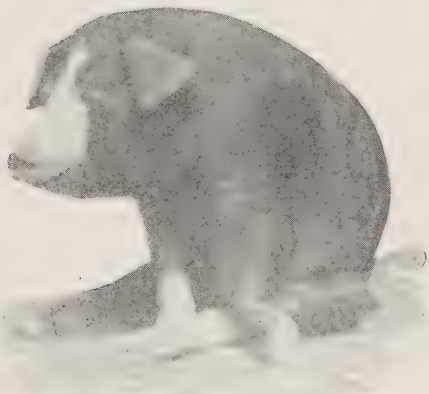
WHITTAKER, H. A., ARCHIBALD, R. W., SHERE, L., and CLEMENT, C. E.
1925. EFFECT OF VARIOUS FACTORS ON THE CREAMING ABILITY OF MARKET MILK. U. S. Dept. Agr. Dept. Bul. 1344.

WRIGHT, O. H. JR.
1923. PASTEURIZATION OF MARKET MILK IN THE GLASS-ENAMELED TANK AND IN THE BOTTLE. So. Dak. Agr. Expt. Sta. Bul. 203.

Bulletin 230 March, 1930

Growth Studies with Swine

by J. H. LONGWELL,
H. O. HENDERSON, and W. M. INSKO, Jr.



Pig Showing Typical Posterior Paralysis Developed on Basal Ration No. 2

UNIVERSITY OF ARIZONA
LIBRARY

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

AGRICULTURAL EXPERIMENT STATION STAFF

JOHN R. TURNER, Ph. D., LL. D.....President of the University
F. D. FROMME, Ph. D.....Dean and Director
GERALD JENNY, M. S.....Agricultural Editor
JOHN C. JOHNSTON.....Chief Clerk

AGRONOMY AND GENETICS

R. J. Garber, Ph. D.
Agronomist and Geneticist

E. P. Deatrick, Ph. D.
Associate Agronomist

W. H. Pierre, Ph. D.
Associate Agronomist

T. C. McIlvaine, Ph. D.†
Assistant Agronomist

D. R. Dodd, B. S.,‡
Assistant Agronomist

M. M. Hoover, M. S.
Assistant Agronomist

H. K. Rowley, M. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, D. Sc.
Animal Husbandman

Chas. V. Wilson, M. S.
Assistant Animal Husbandman

J. H. Longwell, M. A.
Assistant Animal Husbandman

J. H. Rietz, D. V. M.
Associate Veterinarian

R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman

R. S. Glasscock, M. S.**
Assistant in Veterinary Science

CHEMISTRY

R. B. Dustman, Ph. D.
Agricultural Chemist

Chas. E. Weakley, Jr., B. A.
Assistant Chemist

L. P. Hansen, Ph. D.
Assistant Chemist

T. B. Leith, M. S.**
Assistant Chemist

Leland Shriver, B. S. Ch. E.
Assistant in Agricultural Chemistry

DAIRY HUSBANDRY

H. O. Henderson, Ph. D.
Dairy Husbandman

L. M. Thurston, Ph. D.
Assistant Dairy Husbandman

K. S. Morrow, M. S.
Assistant Dairy Husbandman

L. F. Sutton, B. S. Agr.‡
Assistant Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist

W. E. Rumsey, B. S.**
State Entomologist

Edwin Gould, B. S. Agr.
Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist

F. D. Cornell, Jr., M. S.
Assistant Farm Mechanician

W. W. Armentrout, M. S.
Assistant Farm Economist

R. O. Stelzer, B. S.
Assistant in Farm Economics

HOME ECONOMICS

Rachel H. Colwell, M. A.
Home Economist

Hazel C. Cameron, M. A.
Research Specialist in Nutrition

HORTICULTURE

H. E. Knowlton, Ph. D.
Horticulturist

K. C. Westover, M. S. Agr.
Assistant Horticulturist

F. W. Craig, M. S. Agr.**
Assistant Horticulturist

M. B. Hoffman, M. S.
Assistant in Horticulture

E. N. McCubbin, M. A.
Assistant in Horticulture

A. P. Dye, M. S. Agr.
Assistant in Horticulture

PLANT PATHOLOGY

C. R. Orton, Ph. D.
Plant Pathologist

Anthony Berg, M. S.
Associate Plant Pathologist

L. H. Leonian, Ph. D.
Associate Plant Pathologist

F. J. Schneiderhan, M. S.
Associate Plant Pathologist

E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr.
Poultry Husbandman

T. B. Clark, B. S. Agr.
Assistant in Poultry Husbandry

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-Station, Lakin, W. Va.
‡Resigned, February, 1930.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

*Growth Studies with Swine**

by J. H. LONGWELL, H. O. HENDERSON, and W. M. INSKO, Jr.†

THE EXPERIMENTS reported in this bulletin were undertaken with three objects in view: namely, to determine the effects of feeding butterfat; to determine the effects of feeding margarine fats and oils; and to determine the effects of feeding a basal ration free from the known sources of the fat-soluble growth vitamin upon the growth and development of pigs. When this experiment was started in 1923 very little had been published concerning the existence of an antirachitic vitamin—vitamin D—which is also fat-soluble. Although Mellanby *(1921)* and McCollum and coworkers *(1922)* had presented evidence of the existence of a calcium depositing substance in cod-liver oil and butterfat, and of its resistence to oxidation which destroyed vitamin A, very little confirmatory evidence had been published. Later workers confirmed the existence of such a factor and so, in 1926, a new object was added to the experiment: namely, to determine the effect of adding butter and vegetable margarine to a known rachitic ration upon the growth and development of pigs.

This bulletin is a preliminary report on studies begun in 1923 to determine the effect on the growth of pigs of adding butter, oleomargarine, or vegetable margarine to a basal ration deficient in the fat-soluble, growth-promoting vitamin. Up to the present time the effects of the fats upon growth have been measured by the rate and economy of gains made by the pigs, and by observation of the abnormal symptoms exhibited by those pigs suffering from dietary deficiencies. In only one case was a post-mortem examination conducted and a physical examination made of the bones.

Continued investigations on this project will include, in addition to the observations being made, a complete history of the fats used; a study of the ability of the fats to bring about recovery of pigs suffering from avitaminosis; autopsies of all pigs tested; physical examination of bones, including photographic records, hardness tests, and histological examinations; and chemical studies, particularly of the mineral content of the bones.

---

*Submitted for publication October, 1928.
†Mr. Insko resigned July, 1927.

The experimental work for 1923, 1925, and 1926 was under the direction of E. C. Stillwell[1] and Warren Gifford.[2] It was supervised by E. A. Livesay[3] and E. L. Anthony.[4] W. N. McClung, herdsman, had charge of the feeding and weighing of the animals. The oxygenated cod-liver oil used was prepared by R. B. Dustman.[5] All feed analyses were made by the department of agricultural chemistry of the Agricultural Experiment Station.

GENERAL PLAN OF THE EXPERIMENTS

All experiments reported in this bulletin were conducted in dry-lot during the summers of 1923, 1925, 1926, and 1927 by the departments of animal husbandry and dairy husbandry of the West Virginia University on the animal husbandry farm.

The pigs were fed in clean metal troughs in the central hog barn and watered in the same troughs, which were thoroughly cleaned after each feeding. The animals had access to lots having concrete floors, except in 1923, when the runways were of earth. As the runways were in the open, the pigs were exposed to the sun, except in 1927, when the pigs were confined to the barn. The pens were kept as clean as possible in order that the experiments might be relatively free from any disturbing influences of unsanitary surroundings.

Two litters were used in each trial, the pigs of each litter being divided equally among the lots. The pigs were weaned at eight weeks of age and were started immediately on the trial, except in 1925, when the pigs were ten weeks old when started. All of the pigs first were treated for internal parasites, then sprayed with crude oil to kill external parasites. All pigs were weighed individually at intervals of 14 days.

In the original plan of the experiment the basal ration (No. 1) consisted of 5 parts of white corn, 4 parts of whole oats, and 1 part of a mixture of 3 parts of tankage and 1 part of linseed oilmeal. To this basal ration a mineral mixture was added at the rate of one ounce per day for each 100 pounds of live weight. The mineral mixture given in 1923 and 1925 consisted of 5 pounds of acid phosphate, 5 pounds of steamed bone meal, and 1 pound of salt. This mixture was altered in 1926 to 5 pounds of acid phosphate, 5 pounds of steamed bone meal, 5 pounds of ground limestone, and 2 pounds of salt.

As far as was known at the beginning of the experiment this basal ration was free from the fat-soluble growth vitamin. Steenbock and Boutwell *(1920)* showed that white corn contains no appreciable amount of the fat-soluble growth vitamin, although yellow corn contains enough of this substance to allow growth at a normal rate. These experiments have been confirmed with hogs by Livesay and

[1]Now at the Ontario Agricultural College.
[2]Now at the University of Missouri.
[3]Head of the department of animal husbandry.
[4]Then head of the department of dairy husbandry; now at Michigan State College.
[5]Head of the department of agricultural chemistry.

Stillwell *(1927)* of this Station. McCollum and Simmonds *(1925)* state that the grains (wheat, maize, and oats) are deficient in vitamin A.

In 1926 the same basal ration was used as a check ration, and a new basal ration was included, composed of 300 pounds of white corn, 100 pounds of buckwheat middlings, and 20 pounds of tankage. This Station had found that this ration promoted rapid growth for a limited time but was quite deficient in vitamins A and D.

The rations were fed at the rate of 4 pounds per 100 pounds of live weight in 1923. In 1925 and 1926, 5 pounds per 100 pounds of live weight were fed per day, and in 1927, 4½ pounds per 100 pounds of live weight.

All experiments were continued approximately 100 days. Photographs of all lots were taken at the end of the feeding period.

Comparison of Butter and Oleomargarine for Growing Pigs

During the feeding trial of 1923 butter and oleomargarine were compared when added to the basal ration of white corn, oats, tankage, and linseed oilmeal, which was fed to Lot I. One ounce of butter for each 100 pounds of live weight was added to the basal ration of Lot II. The same amount of oleomargarine was added to the basal ration of Lot III.

The butter fed was a good grade of creamery butter that had been carefully stored to avoid aeration. No history of the feeds used in producing this butter was available. The oleomargarine,[7] of the best grades, was composed of oleo oil, neutral oil, cottonseed oil, and milk. Oleo oil is produced from beef fat, more especially the caul and ruffle fat. Neutral oil is made from the leaf fat of the hog. The fats are emulsified in the milk, and after absorbing the milk flavor the product is chilled with water and worked in the same manner as butter, salt being added.

Osborne and Mendel *(1915)* in experiments performed with rats found that when lard was the sole source of fat the animals grew normally for about three months. If the same ration was continued there was a cessation of growth, decline in body weight, and ultimate death. If, however, butter or beef fat was added to the ration, normal growth was continued. The recovery when beef fat was fed after decline was not so marked as when butterfat was fed. The growth-promoting factors were found to be concentrated in the oil of the fat. Halliburton and Drummond *(1917)* as the result of a series of experiments performed with rats concluded: (1) The fat-soluble growth substance is present in beef fat and oleo oil and in margarines prepared on such a basis. These margarines are nutritively the equivalent of butter. (2) Cocoanut oil, cottonseed oil, arachis-oil, and hydrogenated vegetable oils contain little or none of this accessory sub-

[7]A number of articles have been written concerning the relative food value of butter and margarine. The chief difficulty encountered in a study of these articles is the apparent looseness of application of the terms margarine and oleomargarine. To avoid confusion the authors have introduced the trials with oleomargarine and vegetable oil margarine under separate sections. The first section of this bulletin is concerned only with oleomargarine, or margarine containing animal fats.

stance; hence margarines prepared with a basis of these fats do not have a nutritive value equal to that of butter. (3) Nut butters prepared from crushed nuts and vegetable fats similarly are not equal to butter.

In 1923, 15 Poland-China pigs were selected from two litters for the present experiment. One litter contained 6 pigs; the other, 9 pigs. Two pigs were selected from the former and three from the latter for each lot. The three lots were given a preliminary feed of fourteen days on the basal ration, then weighed and started on the experiment.

Lot I received the original basal ration No. 1 and mineral mixture; Lot II, the basal ration, mineral mixture, and two ounces of butter per day for each 100 pounds of live weight; and Lot III, the basal ration, mineral mixture, and two ounces of oleomargarine per day for each 100 pounds of live weight.

TABLE 1.—*Individual and Total Lot Weights by Two-week Periods of Pigs in Three Lots in 1923*

Lots	Weights at Two-week Intervals *(Pounds)*							
	July 19	Aug 2	Aug. 16	Aug. 30	Sept. 13	Sept. 27	Oct. 11	Oct. 25
I								
No. 1	44	52	60	74	87	103	119	137
No. 2	48	54	61	73	85	101	117	130
No. 3	28	31	39	46	58	70	83	91
No. 4	26	27	34	41	50	62	72	84
No. 5	30	33	34	44	50	64	76	92
Total	176	197	228	278	330	400	467	534
II								
No. 1	37	47	51	64	75	94	112	129
No. 2	50	55	67	81	100	121	138	153
No. 3	32	37	44	53	63	78	94	111
No. 4	30	35	39	48	59	75	90	107
No. 5	26	28	33	42	50	66	80	93
Total	175	202	234	288	347	434	514	593
III								
No. 1	44	49	58	70	77	95	112	126
No. 2	48	58	62	74	85	105	122	139
No. 3	28	34	37	43	50	60	68	84
No. 4	25	32	36	47	56	69	82	93
No. 5	32	32	41	49	62	79	92	108
Total	177	205	234	283	330	408	476	550

The increase in weight as found in Lots II and III was not sufficient to pay for the butter and oleomargarine used in feeding. However, as shown in Table 2, the total feed for each 100 pounds of gain was less in the case of the butter lot than in the oleomargarine and check lots. The lot fed oleomargarine required less feed for each 100 pounds of gain than the check lot. The total feed for each 100 pounds of gain was 396 pounds for Lot I, fed the basal ration; 364 pounds for Lot II, receiving the basal ration and butter, and 385 pounds for Lot III, fed the basal ration and oleomargarine.

The total gains of the three lots were 358 pounds for Lot I, 418 pounds for Lot II, and 373 pounds for Lot III. While Lots II and III showed slightly greater gains than Lot I, such gains can be attributed largely to the energy value of the fats added to the rations.

Since there were but 5 pigs per lot, little importance can be attached to the differences in rate and economy of gains between the various lots.

The analysis of feeds fed is shown in Table 3.

Figure 1 shows that the gains of the lots were uniform throughout the feeding period. This graph is based on the total lot weights given in Table 1. The butter lot gained more than either of the other lots. However, the increase over the oleomargarine lot was only 43 pounds, and the oleomargarine lot weighed only 16 pounds more than the check lot at the final weighing. Even though there was a gain

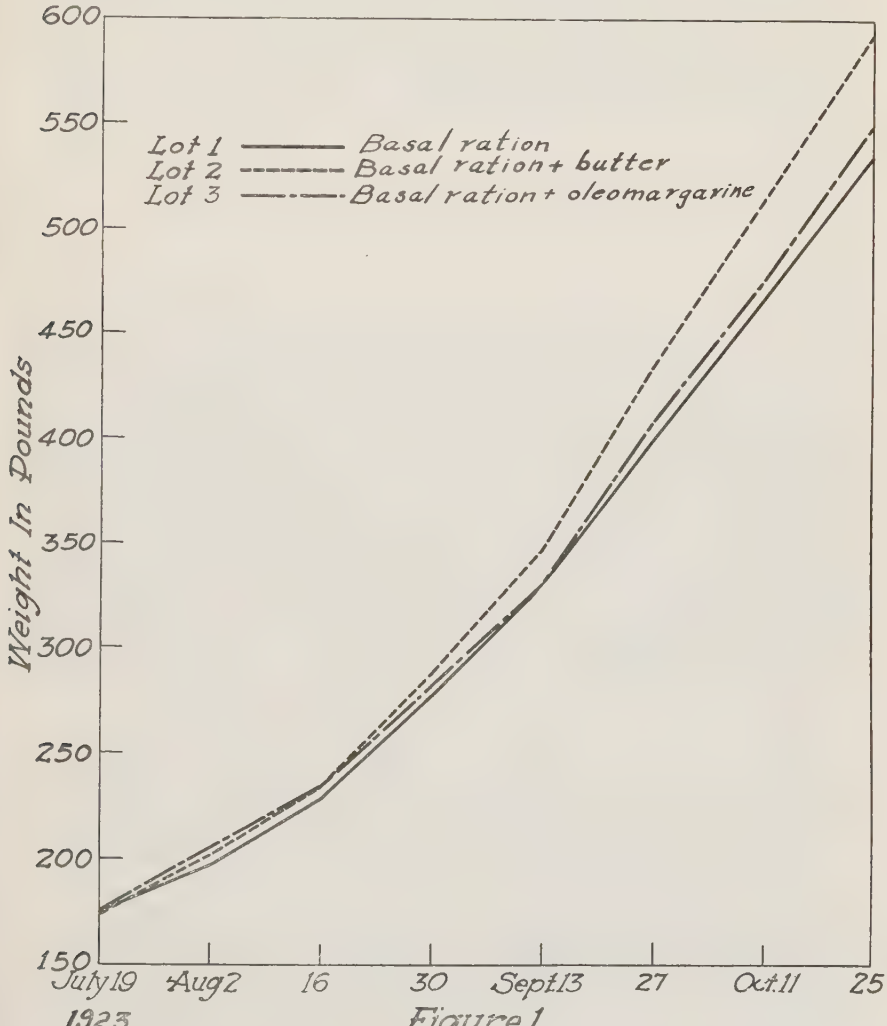


FIGURE 1.—Growth Curves Based on Total Lot Weights as Given in Table 1

over the check ration in each of the lots to which fat was added, the increase was little more than would be expected to result from the energy contained in the fats added to these rations.

TABLE 2.—*Feed and Weight Records of Pigs in Three Lots in 1923*

Item	Rations Fed		
	Lot I	Lot II	Lot III
	Basal Ration* and Mineral Mixture†	Basal Ration, Mineral Mixture, and 1 oz. Butter per 100 Pounds Daily	Basal Ration, Mineral Mixture, and 1 oz. Oleomargarine per 100 Pounds Daily
Number of days on feed	98	98	98
Number of pigs per lot.....	5	5	5
Total gain per lot *(pounds)*	358	418	373
Average initial weight per pig	35.2	35.0	35.1
Average final weight per pig..	106.8	118.6	110.0
Average daily gain per pig...	0.73	0.85	0.76
Total feed per 100 pounds gain	396.1	364.0	385.2

*Basal ration—white corn, 5 parts; oats, 4 parts; tankage (3) and linseed oilmeal (1), 1 part.

†Mineral mixture—acid phospate, 5 pounds; steamed bone meal, 5 pounds; and salt, 1 pound.

FIGURE 2.—Lot I, fed basal ration and mineral mixture (1923)

TABLE 3.—*Analysis of Feeds Fed in 1923*

Feed	Nutrients (Percent)					
	Water	Ash	Crude Protein	Carbohydrates		Fat
				Fiber	N-free Extract	
White Corn ...	10.41	1.41	9.60	1.96	72.78	3.84
Oats*	9.20	3.50	12.40	10.96	59.60	4.40
Tankage	9.50	20.17	58.51	1.46	4.80	5.56
Linseed oilmeal	7.06	5.18	31.47	14.18	35.50	6.61

*Analysis of oats from Henry and Morrison, *Feeds and Feeding.*

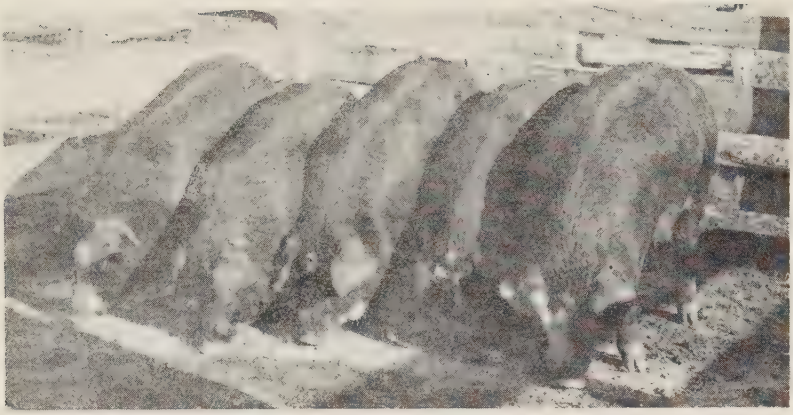


FIGURE 3.—Lot II, fed basal ration, mineral mixture, and butter (1923)

Figures 2, 3, and 4 show the appearance of the lots at the end of the feeding period. As may be observed, Lot II had slightly more finish and was somewhat smoother as well as lightly heavier. Lot III also was smoothly covered and carried more finish than Lot I. Lot I, which received the basal ration, carried less finish than the other two lots although all lots were uniform in weight.

In conclusion it may be said that when butter or oleomargarine was added to a basal ration of white corn, oats, linseed oilmeal, and tankage there was a little increase in weight, due to the added fat or added fat-soluble growth vitamin. The increase was slight, however, and was in favor of the lot receiving butter. This result with pigs substantiates the work with rats as done by Osborne and Mendel *(1915)* and by Halliburton and Drummond *(1917)*.

FIGURE 4.—Lot III, fed basal ration, mineral mixture, and oleomargarine (1923)

Comparison of Butter and Vegetable Margarine (First Trial)

During the feeding trials of 1925 and 1926 butter and vegetable margarine were compared when added to the basal ration. In 1925 the basal ration was the same as in 1923.

Lot I received the basal ration and mineral mixture; Lot II received the basal ration, mineral mixture, and 2 ounces of butter for each 100 pounds of live weight daily; and Lot III received the basal ration, mineral mixture, and 2 ounces of vegetable margarine[8] for each one hundred pounds of live weight daily.

TABLE 4.—*Individual and Total Lot Weights by Two-week Periods of Pigs in Three Lots in 1925*

Lots	Weights at Two-week Intervals *(Pounds)*							
	June 25	July 8	July 22	Aug. 5	Aug. 19	Sept. 2	Sept. 16	Sept. 30
I								
No. 1	50	58	70	89	100	111	146	164
No. 2	40	45	60	73	90	120	134	146
No. 3	46	58	66	84	98	114	128	146
No. 4	46	58	66	89	92	104	124	144
No. 5	53	66	78	91	110	130	154	170
Total	235	285	340	426	490	579	686	770
II								
No. 1	48	61	76	94	112	135	160	192
No. 2	44	55	64	75	91	108	130	144
No. 3	52	64	76	92	112	132	160	180
No. 4	40	50	57	73	87	104	130	145
No. 5	48	64	78	93	113	133	160	185
Total	232	294	351	427	516	612	740	846
III								
No. 1	51	65	76	91	105	123	148	166
No. 2	43	50	61	73	90	106	126	150
No. 3	42	50	56	68	70	92	110	131
No. 4	50	64	75	98	116	133	155	173
No. 5	49	66	78	94	114	136	165	182
Total	235	295	346	424	505	590	704	802

The work of Halliburton and Drummond *(1917)* showed that margarines prepared with a basis of cocoanut oil, cottonseed oil, and hydrogenated vegetable oils are not equal in nutritive value to butter.

Sixteen pigs from two litters were used in the 1926 experiment. Four pigs were placed in each lot. As seen in Figure 6 and Table 7, there was very little variation in the weights of the four lots at the beginning of the experiment. One pig in Lot II died before the end of the feeding trial.

In the trial in 1925 as shown in Table 4, Lot II, which received butter in addition to the basal ration, gained more than either Lot I or Lot III. Lot III, receiving the vegetable margarine in addition to the basal ration, gained more than Lot I, which received only the basal ration.

[8]Nut or vegetable margarine is made in much the same manner as oleomargarine. The ingredients are cocoanut fat, cottonseed, and other vegetable oils. These fats are emulsified with milk. They are then chilled with cold water and worked in the same manner as oleomargarine. Salt is added.

The curves in Figure 5 show that the gains in all lots were uniform and, considering the greater energy intake in Lots II and III, practically equal.

As shown in Table 5, the lot receiving the butter required the smallest number of pounds of feed for each 100 pounds of gain. This lot required 387.3 pounds, while Lot III required 409.7 pounds, and Lot I, 414.6 pounds. As with the 1923 trial, the differences in rate and economy of gains may be credited principally to the greater energy intake in the lots receiving fat. The analysis of feeds fed in 1925 is given in Table 6.

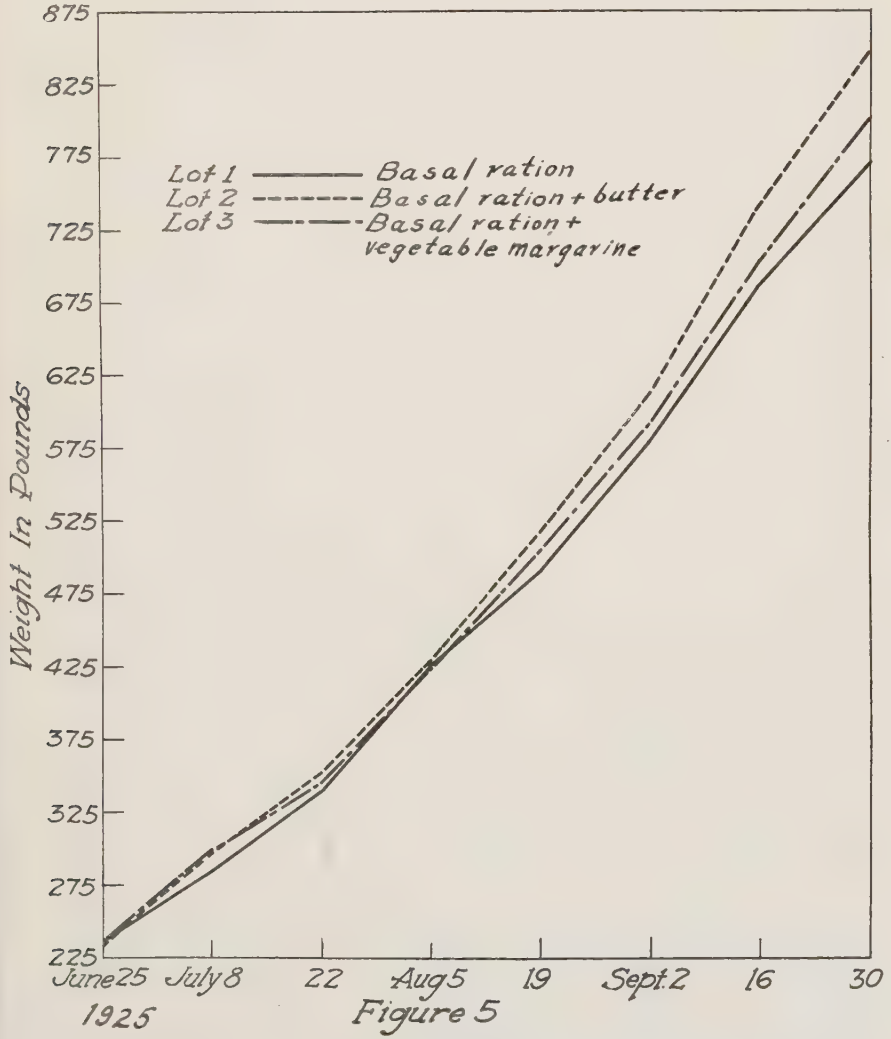


FIGURE 5.—Growth Curves Based on Total Lot Weights as Given in Table 4

Comparison of Butter and Vegetable Margarine (Second Trial)

Since the trials of 1923 and 1925 had shown only slight differences in the rate of gains and in the economy of gains between the lots fed the check rations and those fed the check rations plus butter, or plus oleomargarine, or plus vegetable margarine, it was decided to substitute a new basal ration in 1926. During the winter feeding trials reported by Livesay and Stillwell *(1926)* pigs receiving a ration of white corn, buckwheat middlings, and tankage developed rickets, going down on the seventieth day of the feeding trial. These pigs, however, made good gains and quickly recovered when fed either untreated or oxygenated cod-liver oil. The treated oil was prepared according to the directions of McCollum and Simmonds *(1925)*.

With the purpose of obtaining data on the existence of the antirachitic vitamin (vitamin D) in butter and vegetable margarine, the winter basal ration was substituted for the basal ration used in the two previous summers. This new ration (Basal Ration No. 2) was composed of white corn, 300 pounds; buckwheat middlings, 100 pounds; tankage, 20 pounds; and a mineral mixture composed of 5 pounds of steamed bonemeal, 5 pounds of ground limestone, 5 pounds of acid phosphate, and 2 pounds of salt.

Lot I received the original basal ration of white corn, oats, linseed oilmeal, and tankage, plus the mineral mixture. Lot II received the new basal ration and the mineral mixture. Lot III received the new basal ration, mineral mixture, and 2 ounces of butter for each 100 pounds of live weight daily. Lot IV received the new basal

TABLE 5.—*Feed and Weight Records of Pigs in Three Lots in 1925*

Item	Rations Fed		
	Lot I	Lot II	Lot III
	Basal Ration* and Mineral Mixture	Basal Ration, Mineral Mixture, and 2 oz. Butter per 100 Pounds Daily	Basal Ration, Mineral Mixture, and 2 oz. Vegetable Margarine per 100 Pounds Daily
Numbers of days on feed.....	98	98	98
Number of pigs per lot.....	5	5	5
Total gain per lot *(pounds)*....	535	614	567
Average initial weight per pig	47.0	46.4	47.0
Average final weight per pig..	154.0	169.2	160.4
Average gain per pig	107.0	122.8	113.4
Average daily gain per pig...	1.09	1.25	1.16
Total feed per 100 pounds gain	414.6	387.3	409.7

*Basal ration—white corn, 5 parts; oats, 4 parts; tankage (3) and linseed oilmeal (1), 1 part.

TABLE 6.—*Analysis of Feeds Fed in 1925*

Feed	Nutrients (Percent)					
	Water	Ash	Crude Protein	Carbohydrates		Fat
				Fiber	N-free Extract	
White corn	13.21	1.25	8.33	2.49	71.79	2.93
Oats	8.36	3.27	10.09	11.17	62.28	4.83
Tankage	7.71	21.60	59.36	1.20	2.33	7.80
Linseed oilmeal .	8.83	5.31	34.10	8.44	37.25	6.07

ration, mineral mixture, and 2 ounces of vegetable margarine for each 100 pounds of live weight daily.

Since pig No. 3 in Lot II died on the 89th day of the feeding trial, the average consumption of feed for each 100 pounds of gain was calculated on the nearest weigh day. This was the 84th day of the trial. As shown in Table 8, Lot I consumed 340 pounds per 100 pounds of gain; Lot II, 334 pounds; Lot III, 330 pounds; and Lot IV, 340 pounds. The differences in rate and economy of gains are not important. The weights for the succeeding weigh periods are given in Table 7.

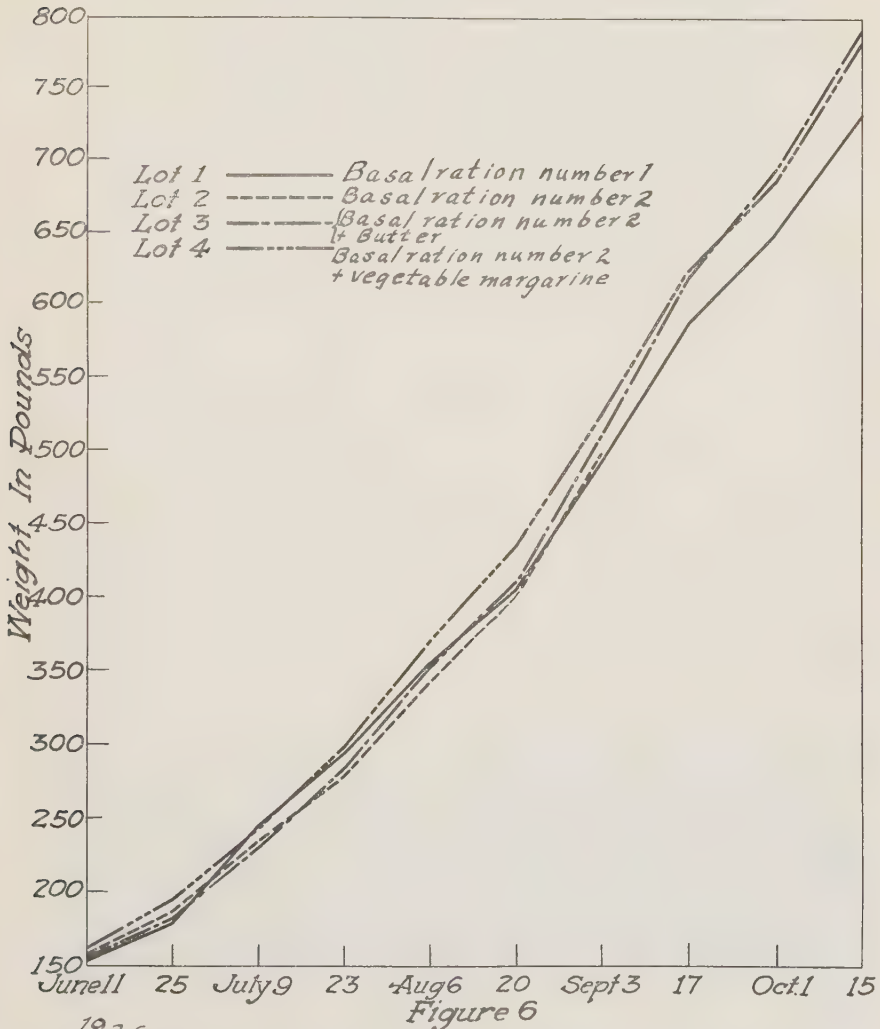


FIGURE 6.—Growth Curves Based on Total Lot Weights as Given in Table 7

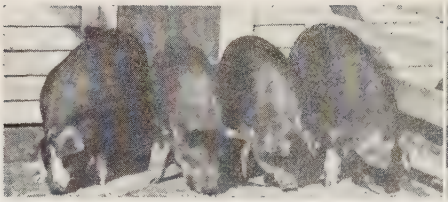


FIGURE 7.—Lot I, Fed Basal Ration No. 1 and Mineral Mixture (1926)

FIGURE 8.—Lot II, Fed Basal Ration No. 2 and Mineral Mixture (1926)

TABLE 7.—*Individual and Total Lot Weights by Two-week Periods of Pigs in Four Lots in 1926*

Lots	Weights at Two-week Intervals *(Pounds)*									
	June 11	June 25	July 9	July 23	Aug. 6	Aug. 20	Sept. 3	Sept. 17	Oct. 1	Oct. 15
I										
No. 1	44	52	66	80	96	108	158	137	180	190
No. 2	48	54	68	80	96	110	150	132	166	186
No. 3	38	46	60	74	88	102	141	119	154	178
No. 4	24	26	52	60	74	84	139	104	150	176
Total	154	178	246	294	354	404	492	588	650	730
II										
No. 1	52	58	68	80	94	112	137	172	186	210
No. 2	32	38	52	62	76	94	116	128	158	180
No. 3	40	46	60	72	90	104	129	died September 8		
No. 4	34	44	54	66	82	90	115	140	146	168
Total	158	186	234	280	342	400	497	440	490	554
III										
No. 1	54	58	76	90	108	124	158	181	204	230
No. 2	38	44	52	68	84	98	118	145	168	188
No. 3	30	38	48	58	76	92	114	140	156	184
No. 4	34	42	54	68	84	96	122	154	166	186
Total	156	182	230	284	352	410	510	620	694	788
IV										
No. 1	52	56	60	72	102	84	118	158	172	200
No. 2	46	56	68	82	122	100	152	172	196	224
No. 3	30	40	52	66	98	82	116	130	144	160
No. 4	34	44	64	80	114	104	140	162	174	200
Total	162	196	244	300	370	426	526	622	686	784

FIGURE 9.—Lot III, Fed Basal Ration No. 2, Mineral Mixture, and Butter (1926)

FIGURE 10.—Lot IV, Fed Basal Ration No. 2, Mineral Mixture, and Vegetable Margarine (1926)

The analysis of feeds fed in 1926 is given in Table 9.

The lots at the final weigh period are shown in Figures 7 to 10 inclusive. Lots III and IV were more uniform and smoother than Lots I and II. However, all lots were in good condition and brought an excellent price on the market. Pig No. 3 of Lot II was given a post-mortem examination with the results as shown in Figures 12 to 16, inclusive.

FIGURE 11.—A pig from Lot II showing posterior paralysis (1926)

As shown in Table 8, two pigs from Lot II and two pigs from Lot IV developed rickets, going down on the 86th day. Since rickets had developed in the lots receiving the new basal ration during the preceding winter feeding trials, this development was expected in Lot II. On the 81st day, signs of the approaching trouble were first noticed in the two lots. The symptoms were nervousness, drooping ears, failure to eat, reddening of eyes, and wobbly gait. Although the eye trouble was not uniform, in one case it approached blindness. On the 86th day two pigs of each lot went down, unable to rise.

The pigs of Lot II were given untreated cod-liver oil and those of Lot IV oxygenated cod-liver oil at the rate of 25 c. c. for each 100 pounds of live weight daily. One pig of Lot II failed to recover, dying on the 89th day. The other pigs recovered; the three which had collapsed were on their feet fourteen days after they went down and were in good condition twenty-six days after the treatment began.

Although post-mortem examination showed the lack of calcification of the ribs and femur, as well as vertebral fracture, the external condition was most noticeable as posterior paralysis. As shown in Figure 11 and on the cover, the animal lost control of the hind quarters and was unable to stand. The direct cause of this trouble was the fracture of the fifth vertebra of the loin or lumbar region. This vertebra pressed upon the spinal cord (Figures 12 to 14), thus causing deadening or paralysis of the nerves controlling the movement of the rear portion of the body.

Post-mortem examination showed that the ribs were beaded. The femurs showed porous areas, and both ribs and femurs showed areas

TABLE 8.—*Feed and Weight Records of Pigs in Four Lots in 1926*

Item	Rations Fed			
	Lot I	Lot II	Lot III	Lot IV
	Basal Ration No. 1* and Mineral Mixture	Basal Ration No. 2† and Mineral Mixture	Basal Ration No. 2,† Mineral Mixture, and 2 oz. of Butter per 100 Pounds Daily	Basal Ration No. 2,† Mineral Mixture, and 2 oz. of Vegetable Margarine per 100 Pounds Daily
Number of days on feed	84	84	84	84
Number of pigs per lot	4	4	4	4
Total gain per lot *(pounds)*	338	339	354	364
Initial weight per pig	38.5	39.5	39.0	40.5
Final weight per pig	123.0	124.2	127.5	131.5
Total gain per pig	84.4	84.7	88.5	91
Daily gain per pig	1.00	1.00	1.05	1.08
Total feed per 100 pounds gain	340.0	334.0	330.0	349.0
Number of pigs going down	0	2	0	2
Days on feed before developing rickets	....	86‡	....	86‡
Pigs dying	0	1	0	0

*Basal ration No. 1—white corn, 5 parts; oats, 4 parts; tankage (3) and linseed oilmeal (1), 1 part.
†Basal ration No. 2—white corn, 300 pounds; buckwheat middlings, 100 pounds; tankage, 20 pounds.
‡Two pigs in Lot II and two in Lot IV went off feed on the 86th day and one pig in Lot II died on the 89th day; hence feed and weight records are calculated to the nearest weigh day, the 84th day.

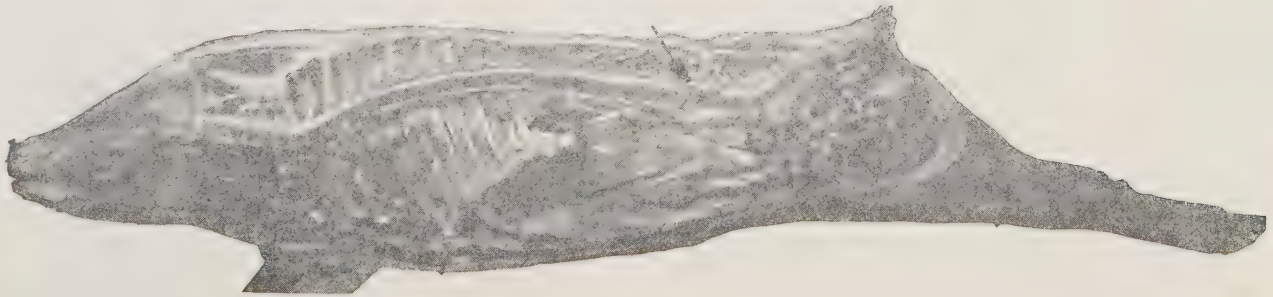


FIGURE 12.—One Side of the Pig Shown in Figure 11. The Fracture of the Lumbar Vertebra and the Beading of the Ribs are Very Distinct

of fresh calcification at the tips. (Figures 15 and 16). This examination would lead to the belief that the pathological condition was due to the lack of vitamin D, since there was present in the mineral mixture sufficient bone-producing substance, which apparently was not assimilated.

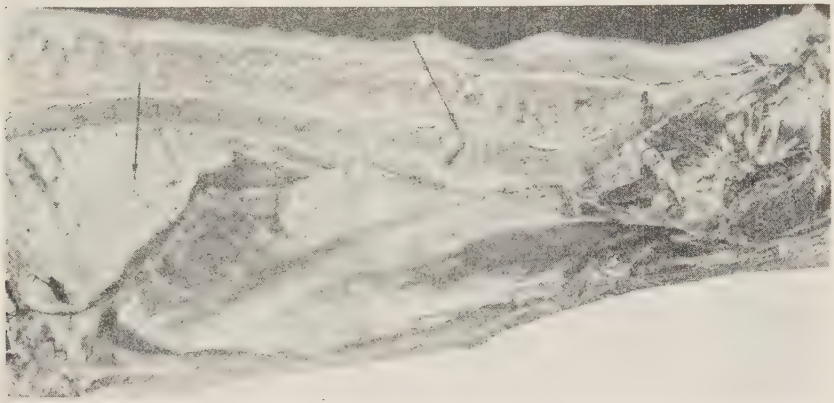


FIGURE 13.—A portion of the side shown in the previous figure. Note the fracture of the lumbar vertebra and the beading of the ribs due to the failure to assimilate the mineral of the ration

TABLE 9.—*Analysis of Feeds Fed in 1926*

Feed	Nutrients (Percent)					
	Water	Ash	Carbohydrates		N-free Extract	Fat
			Crude Protein	Fiber		
White Corn	11.39	1.43	8.67	2.56	72.15	3.50
Oats	7.63	2.51	11.33	11.63	62.10	4.80
Tankage	7.61	26.23	50.45	2.00	12.40	7.31
Linseed oilmeal	8.31	4.57	33.63	9.38	38.53	5.58
Buckwheat middlings	9.73	2.84	22.98	6.07	53.18	5.20

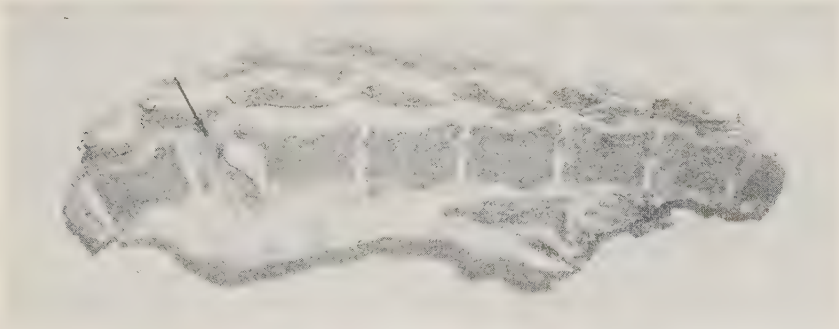


FIGURE 14.—The fractured lumbar vertebra causing posterior paralysis. The pig from which this backbone was taken had received a ration of white corn, buckwheat middlings, and tankage, with a mineral mixture

Since there was no evidence of lack of assimilation of bone-producing materials in Lot III, which received butter, it is apparent that over a period of 126 days there is present enough vitamin D in butter to prevent rickets. The basal ration consisting of white corn, buckwheat middlings, and tankage contained very little, if any, vitamin D, and therefore Lot II, receiving this ration, developed rickets. Lot IV, receiving vegetable margarine in addition to the basal ration, also developed rickets. This lot was returned to normal by the use of oxygenated cod-liver oil.

Lot I, receiving a ration of white corn, oats, linseed oilmeal, and tankage, did not develop rickets. This result supports previous work at this Station which indicates that oats in the ration will prevent rickets during a limited feeding period. This work is being continued to determine more definitely the anti-rachitic properties of whole oats.

Comparison of Butter, Oleomargarine, and Nut Margarine

Before 1927 no more than two of the fats in question had been compared at one time. In the trial for this year, therefore, all three were fed.

Conditions of feeding were similar to those in previous years except that all pigs were fed inside the barn and were not exposed to sunlight at any time during the trial.

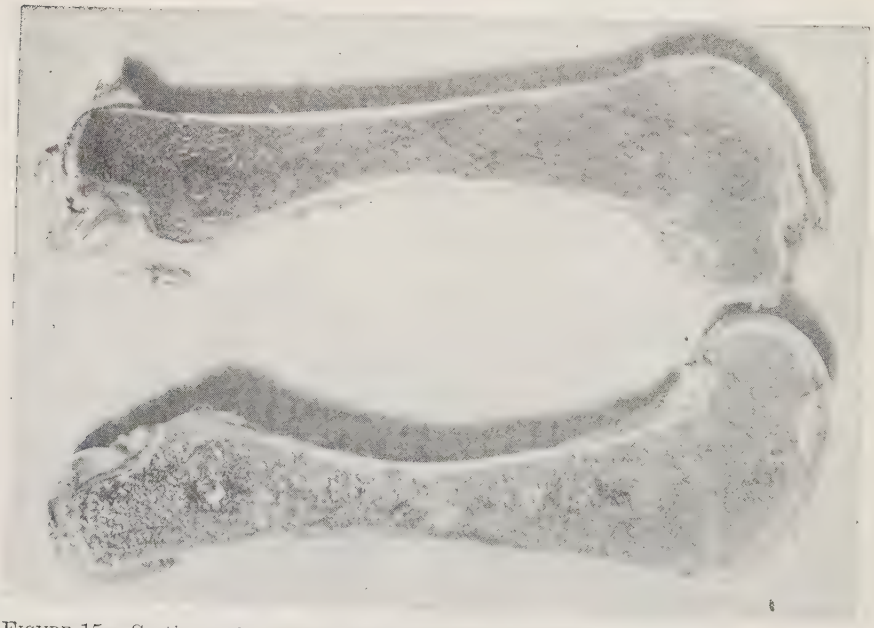


FIGURE 15.—Sections of a femur from a pig affected with rickets. Note the areas of poor calcification

TABLE 10.—*Summary of Feed and Weight Records of Pigs in Four Lots in 1927*

Item	Division of Pigs			
	Lot I	Lot II	Lot III	Lot IV
Number of pigs	4	4	4	4
Total initial weight *(pounds)*	167	164	166	166
Total final weight	853	921	868	830
Total gain	686	757	702	664
Average initial weight	41.8	41.0	41.5	41.5
Average final weight	213.3	230.3	217.0	207.5
Average gain	171.5	189.3	175.5	166.0
Number of days on experiment	127	127	127	127
Average daily gain	1.35	1.49	1.38	1.30
Feed Consumed				
White corn *(pounds)*	1864.8	1864.0	1824.5	1738.5
Buckwheat middlings	621.6	621.4	608.2	579.5
Tankage	124.3	124.3	121.6	116.9
Lard	74.4			
Butter		89.6		
Oleomargarine			85.5	
Nut margarine				82.1
Mineral	87.2	89.6	85.5	82.1
Total	2772.3	2788.9	2725.3	2598.1
Feed consumed per 100 pounds gain				
White corn	271.80	246.20	259.90	261.80
Buckwheat middlings	90.6	82.1	86.6	87.3
Tankage	18.1	16.4	17.3	17.5
Lard	10.8			
Oleomargarine			12.2	
Nut margarine				12.4
Butter		11.6		
Mineral	12.7	11.6	12.2	12.4
Total	404.1	367.8	388.2	391.2
Pigs showing eye trouble, nervousness, and labored breathing	4	0	0	4
Pigs showing incoordination and paralysis	2	0	0	2
Pigs dying	0	0	0	1

The pigs in each lot received the same basal ration, consisting of 300 pounds of white corn, 100 pounds of buckwheat middlings, and 20 pounds of tankage. The pigs were weighed every two weeks and were fed this mixture at the rate of 4.5 pounds of feed for each 100 pounds of live weight, the daily amount remaining constant until the next weigh day. The pigs were fed twice daily. Toward the end of the experiment the pigs failed to clean up this amount of feed, so that the ration was reduced to 4 percent of the live weight. This was true in the case of the normal pigs as well as those showing symptoms of avitaminosis. All lots received a mineral mixture at the rate of 2 ounces for each 100 pounds of live weight daily.

Lot I, the check lot, received enough lard to maintain the energy intake on the same level as in the other lots. The lard used was high-quality open-kettle-rendered leaf lard. Work by Osborne and Mendel *(1915)* indicates that lard contains little or no vitamin A or D. Lot II received 2 ounces of butter; Lot III, 2 ounces of oleomargarine; and Lot IV, 2 ounces of vegetable margarine for each 100 pounds of live weight daily.

Two litters of pigs were employed, one litter being purebred Berkshires and the other being sired by a Berkshire boar and out of a Duroc-Jersey sow. It was necessary to use nine of the cross-breds

and seven purebreds, making three cross-breds and one purebred, in Lot II. The pigs were all of the same age, about ten weeks old when put on feed.

Table 10 gives a summary of the feed and weight records. These pigs went for a longer period than any previous group before showing any symptoms of avitaminosis. The rate of gains was quite satisfactory in all lots. Table 11 gives individual weights by two-week periods for the 16 pigs. Figure 17 shows the total lot weights of these pigs.

Tables 10 and 11 show that all lots received adequate amounts of energy to make satisfactory gains. As in previous trials, the small

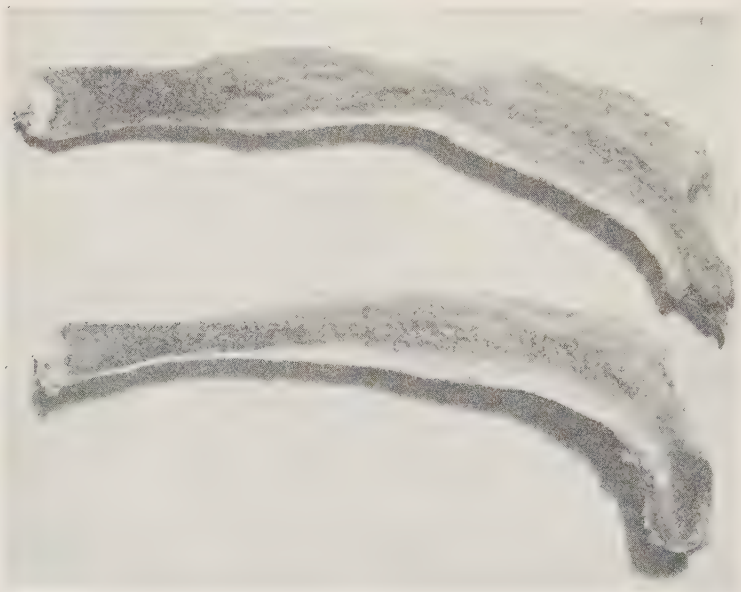


FIGURE 16.—Sections of ribs from a pig affected with rickets. Note the areas of porous bone, the thickening of the rib on the right, and the area of fresh calcification at the end of the bone

number of pigs does not justify any comparison of the value of the rations as measured by gains on pigs or by amounts of feed per unit of gain.

On November 18 the pigs in Lots I and IV began to leave feed in their troughs. They were fed night and morning, but some feed remained in the troughs 4 or 5 hours before being eaten. Lots II and III cleaned up their feed within 15 minutes. On December 1 the pigs in Lot I were in poor condition, had poor appetites, were sluggish, and had dull hair. Pig "3XS" of this lot was in especially bad condition, the eyes being red and watery, in addition to the other symptoms mentioned. On December 8 pig "3XS," Lot I, and pig "1XS," Lot

TABLE 11.—*Individual and Total Lot Weights by Two-week Periods of Pigs in Four Lots in 1927*

Lot	Pig	Weights at Two-week Intervals *(Pounds)*									
		Aug. 11	Aug. 25	Sept. 8	Sept. 22	Oct. 6	Oct. 20	Nov. 3	Nov. 17	Dec. 1	Dec. 15
I	3XS	45	72	64	102	133	150	175	209	225	235
	0BS	34	46	47	56	96	116	148	169	205	218
	10BS	32	40	76	75	72	90	117	151	163	181
	10XS	56	74	90	104	132	154	182	210	217	219
	Total	167	232	277	341	433	510	622	739	810	853
II	1XB	47	59	52	82	94	114	139	158	186	197
	0XB	32	46	61	63	84	109	134	166	200	224
	30XB	49	68	84	105	122	163	194	229	260	279
	30BS	36	53	89	98	103	124	145	178	194	221
	Total	164	226	286	328	403	510	612	731	840	921
III	0XS	45	66	82	96	125	144	167	190	213	232
	90BS	38	44	56	66	84	108	135	162	182	198
	9XB	50	69	87	99	123	150	173	202	230	245
	30BB	33	43	52	62	78	88	133	158	165	193
	Total	166	222	277	323	410	500	608	712	800	868
IV	0BB	38	43	60	70	83	104	130	164	193	217
	3XB	57	78	93	102	123	145	165	196	221	242
	1XB	33	47	65	77	101	123	151	166	177	171
	3BB	38	48	51	64	84	98	130	158	183	200
	Total	166	216	269	313	391	470	576	684	774	830

IV, had badly inflamed eyes, walked with an uncertain, staggering gait in the hind quarters, and were quite nervous. Lots II and III were in good thrifty condition on this date.

The pigs were removed from experiment on December 15. At this time all pigs in Lots I and IV showed inflammation of the eyes and lack of co-ordination in hind quarters, and were very nervous and restless. Pigs "10XS," Lot I, and "1XS," Lot IV, were especially

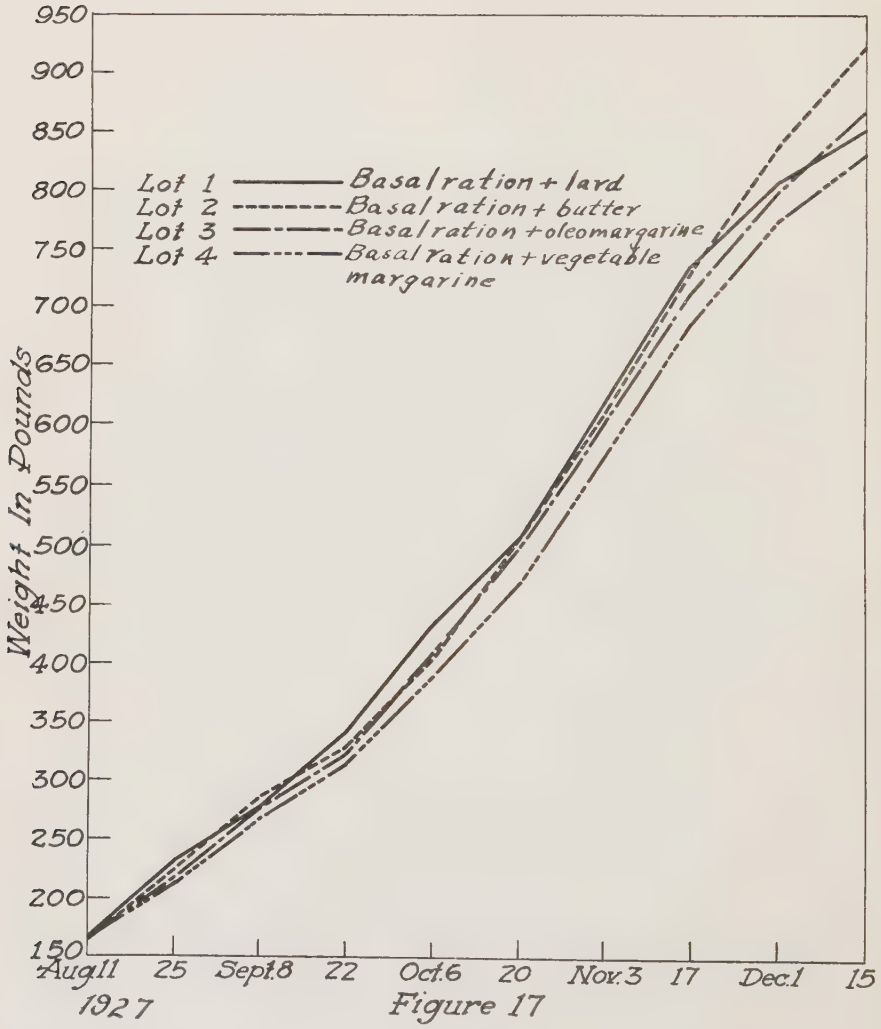


FIGURE 17.—Growth Curves Based on Total Lot Weights as Given in Table 11

As seen in Figure 17, gains were rapid and uniform in all lots until December 1, when Lot I and Lot IV began to go down.

affected. "0BB" and "3BB," Lot IV, were quite restless and affected with short, labored, convulsive breathing. "3BB" had attacks of partial paralysis and at times was unable to rise. All pigs in Lots II and III were thrifty and gaining well.

Immediately after being removed from the experiment each pig in Lots I and IV was given a tablespoonful of oxygenated cod-liver oil, the dose being repeated each morning and evening and the ration being kept the same. On December 18 "3BB," Lot IV, died. All the other pigs showed immediate and marked improvement in co-ordination. The eyes, however, still remained sore, and the pigs suffering from difficult breathing showed no improvement. On December 19 yellow corn was substituted for the white corn of the ration, and untreated cod-liver oil was given. All pigs showed marked improvement and were apparently normal on December 29.

SUMMARY

Four years' work in comparing butter, oleomargarine, and vegetable oil margarine as sources of fat-soluble vitamin for pigs are reported.

In 1923 three lots of pigs received a basal ration of white corn, oats, tankage, and linseed oilmeal. To the ration of Lot II was added one ounce of butter for each 100 pounds of live weight, and to the basal ration of Lot III was added one ounce of oleomargarine for each 100 pounds of live weight. During the feeding period of 98 days the pigs of Lots II and III gained slightly more than Lot I, the check lot, but the difference was not great enough to be considered important.

In 1925 similar results were obtained by feeding the same basal ration, but using vegetable oil margarine in place of oleomargarine in Lot III.

Pigs receiving a ration of white corn, buckwheat middlings, and tankage in the 1926 trial developed rickets, two animals going down on the 86th day. One animal died and was examined. The examination showed a fractured lumbar vertebra, beading of the ribs, and abnormal calcification of the femurs. Oxygenated cod-liver oil brought about recovery. One of the pigs receiving untreated cod-liver oil died. The lot receiving the basal ration plus butter showed no symptoms of rickets during the 126-day feeding period. The check lot, which received white corn, oats, tankage, and linseed oilmeal did not develop rickets.

Four lots of pigs received the known rachitic ration of white corn, buckwheat middlings, and tankage in the 1927 trial. Lot II received 2 ounces of butter per 100 pounds of live weight daily; Lot III, two ounces of oleomargarine; Lot IV, two ounces of vegetable oil margarine; and Lot I, sufficient lard to maintain the energy intake on the

same level as that of the other three lots. Lot I, receiving the lard, and Lot IV, receiving the vegetable oil margarine, developed symptoms of vitamin A and D deficiency in 100 to 110 days. Butter and oleomargarine appeared to be equally effective in preventing the trouble for a period of 126 days.

LITERATURE CITED

HALLIBURTON, W. D., and DRUMMOND, J. C.
1917. THE NUTRITIVE VALUE OF MARGARINE AND BUTTER SUBSTITUTES WITH REFERENCE TO THEIR CONTENT OF THE FAT-SOLUBLE ACCESSORY GROWTH SUBSTANCE. Jour. Physiol. 51, 235.

LIVESAY, E. A., and STILLWELL, E. C.
1926. THE INFLUENCE OF THE ADDITION OF OATS TO A WHITE CORN RATION IN GROWING AND FATTENING PIGS. Proc. Amer. Soc. An. Prod.

———, ———
1927. COMPARATIVE TESTS OF CERTAIN FEEDS IN RATIONS FOR PIGS. W. Va. Exp. Sta. Bul. 213.

MELLANBY, E.
1921. EXPERIMENTAL RICKETS.
Med. Res. Council, London.

MCCOLLUM, E. V., SIMMONDS, N., SHIPLEY, P. G., and PARK, E. A.
1922. IS THERE A SUBSTANCE OTHER THAN FAT-SOLUBLE A ASSOCIATED WITH CERTAIN FATS, WHICH PLAYS AN IMPORTANT ROLE IN BONE DEVELOPMENT?
Jour. Biol. Chem. 50, 5.

———, ———
1925. THE NEWER KNOWLEDGE OF NUTRITION.
3rd edition, 84.

———, ———
1925. THE NEWER KNOWLEDGE OF NUTRITION.
3rd edition, 405.

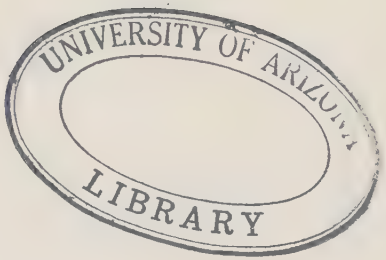
OSBORNE, T. B., and MENDEL, L. B.
1915. FURTHER OBSERVATIONS OF THE INFLUENCE OF NATURAL FATS UPON GROWTH.
Jour. Biol. Chem. 20, 379.

STEENBOCK, H., and BOUTWELL, P. W.
1920. THE COMPARATIVE NUTRITIVE VALUE OF WHITE AND YELLOW MAIZE.
Jour. Biol. Chem. 41, 81.

Bulletin 231 March, 1930

The Effect of Feeding Different Amounts of Calcium and Phosphorus upon the Growth and Development of Dairy Animals

by H. O. HENDERSON and C. E. WEAKLEY, JR.



AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

AGRICULTURAL EXPERIMENT STATION STAFF

JOHN R. TURNER, Ph. D., LL. D.....President of the University
F. D. FROMME, Ph. D.....Dean and Director
GERALD JENNY, M. S.....Agricultural Editor
JOHN C. JOHNSTON.....Chief Clerk

AGRONOMY AND GENETICS

R. J. Garber, Ph. D.
Agronomist and Geneticist
E. P. Deatrick, Ph. D.
Associate Agronomist
W. H. Pierre, Ph. D.
Associate Agronomist
T. C. McIlvaine, Ph. D.†
Assistant Agronomist
D. R. Dodd, B. S.,‡
Assistant Agronomist
M. M. Hoover, M. S.
Assistant Agronomist
H. K. Rowley, M. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, D. Sc.
Animal Husbandman
Chas. V. Wilson, M. S.
Assistant Animal Husbandman
J. H. Longwell, M. A.
Assistant Animal Husbandman
J. H. Rietz, D. V. M.
Associate Veterinarian
R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman
R. S. Glasscock, M. S.**
Assistant in Veterinary Science

CHEMISTRY

R. B. Dustman, Ph. D.
Agricultural Chemist
Chas. E. Weakley, Jr., B. A.
Assistant Chemist
L. P. Hansen, Ph. D.
Assistant Chemist
T. B. Leith, M. S.**
Assistant Chemist
Leland Shriver, B. S. Ch. E.
Assistant in Agricultural Chemistry

DAIRY HUSBANDRY

H. O. Henderson, Ph. D.
Dairy Husbandman
L. M. Thurston, Ph. D.
Assistant Dairy Husbandman
K. S. Morrow, M. S.
Assistant Dairy Husbandman
L. F. Sutton, B. S. Agr.‡
Assistant Dairy Husbandman

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist
W. E. Rumsey, B. S.**
State Entomologist
Edwin Gould, B. S. Agr.
Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist
F. D. Cornell, Jr., M. S.
Assistant Farm Mechanician
W. W. Armentrout, M. S.
Assistant Farm Economist
R. O. Stelzer, B. S.
Assistant in Farm Economics

HOME ECONOMICS

Rachel H. Colwell, M. A.
Home Economist
Hazel C. Cameron, M. A.
Research Specialist in Nutrition

HORTICULTURE

H. E. Knowlton, Ph. D.
Horticulturist
K. C. Westover, M. S. Agr.
Assistant Horticulturist
F. W. Craig, M. S. Agr.**
Assistant Horticulturist
M. B. Hoffman, M. S.
Assistant in Horticulture
E. N. McCubbin, M. A.
Assistant in Horticulture
A. P. Dye, M. S. Agr.
Assistant in Horticulture

PLANT PATHOLOGY

C. R. Orton, Ph. D.
Plant Pathologist
Anthony Berg, M. S.
Associate Plant Pathologist
L. H. Leonian, Ph. D.
Associate Plant Pathologist
F. J. Schneiderhan, M. S.
Associate Plant Pathologist
E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr.
Poultry Husbandman
T. B. Clark, B. S. Agr.
Assistant in Poultry Husbandry

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-Station, Lakin, W. Va.
‡Resigned, February, 1930.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

*The Effect of Feeding Different Amounts of Calcium and Phosphorus upon the Growth and Development of Dairy Animals**

by H. O. HENDERSON and C. E. WEAKLEY, JR.†

IT HAS long been known that calcium and phosphorus are necessary in the rations of farm animals if they are to grow and have normal development. It was generally supposed, however, that any ration which supplied sufficient protein, carbohydrates, and fat to meet the requirements of the growing animal would also supply sufficient amounts of these two minerals. For this reason very little consideration has been given to the optimum amount of calcium and phosphorus required for normal growth and development of the dairy heifer.

In recent years much experimental work in mineral metabolism has emphasized the importance of calcium and phosphorus in the ration and has shown that these elements sometimes may not be present in sufficient amounts for normal growth and development. Within the last decade a dietary factor has been discovered which aids in the assimilation of calcium and phosphorus. The ultra-violet rays, when animals are exposed to them, also have the power to help with this assimilation. Most of such studies have been made with small laboratory animals or with such domestic animals as the chicken, the pig, or the dairy cow, but very little has been done with the growing dairy animal.

It has also been shown recently that in many sections of the country the soil is deficient in calcium or, more especially, in phosphorus, to the extent that the forage grown on it will not support normal growth and development in dairy heifers. This has led to the belief, fully substantiated, that some of the roughage grown in various parts of the country may be extremely low in one or both of these elements.

There has been a tendency also in late years toward the feeding of more and more by-products of milling and other industries. Such feeds are also quite low in one or both of these elements, with a correspondingly greater chance that a ration may be deficient in these minerals.

*Submitted for publication March, 1929.

†The material in this bulletin was presented by the senior author in partial fulfillment of the requirements for the degree of doctor of philosophy at the University of Minnesota. He is indebted to Dr. C. H. Eckles and Dr. L. S. Palmer of the Minnesota Agricultural Experiment Station for help in outlining the investigation described and for many helpful suggestions received during the entire period of investigation.

With these points in mind it seemed important that a study of the requirements of the growing dairy heifer for calcium and phosphorus be made. The investigations herein reported were made to determine the effects upon the growing dairy heifer of feeding rations containing various amounts of calcium and phosphorus. The study was not intended to determine the exact requirements for calcium and phosphorus because of the many other factors involved, but was made as a contribution toward that end. When we consider that more than 4,500,000 dairy calves must be raised each year in order to maintain the present supply of dairy cows, the importance of additional information in this direction is readily apparent.

REVIEW OF LITERATURE

The deposition of calcium and phosphorus in the animal body has been a field of study for many years. Among the earlier investigators who studied the effects of rations low in minerals upon animals were Chossat *(1842)*, who worked with pigeons; Weiske *(1872)*, and Weiske and Wildt *(1873)*, who used goats and lambs; Forster *(1873)* who employed pigeons and later dogs; Voit *(1880)* who also used pigeons and dogs; and Aron and Sebauer *(1908)* who worked upon rabbits and dogs. These investigators demonstrated the necessity of minerals in the diet.

Later studies by Osborne and Mendel *(1918)* have shown that the rat will not develop unless given sufficient minerals in its diet. Sherman and Pappenheimer *(1921)* and McCollum and co-workers *(1921)* have shown that rickets in rats can be produced by feeding rations low in one or both of these minerals.

A trouble known as leg weakness in chickens also has been attributed to the lack of sufficient minerals in the ration and has been described by Hart, Halpin, and Steenbock *(1920)* as a form of rickets which occurs when baby chicks are kept in confinement and when the chicks are from 4 to 8 weeks old.

Maynard, Goldberg, and Miller *(1925)*, Bohstedt *(1926)* and co-workers *(1927)*, and others have shown that when pigs are fed rations low in calcium, posterior paralysis results. This condition is due to a broken vertebra pressing upon the spinal cord. Somewhat similar results were obtained by Hart, McCollum, and Fuller *(1909)* when pigs were fed rations low in phosphorus.

The effects of feeding rations low in calcium and phosphorus to cattle also have been noted within recent years. The occurrence of abnormal conditions in cattle due to a mineral deficiency has been reported in various parts of the United States. In such sections the soil is so deficient in calcium, and more often in phosphorus, that the forage grown upon it is low in its content of these two minerals. In such sections the cattle very often are stunted, showing extreme emaciation, stiffness in the hind quarters and also at times in the front quarters, swollen joints, harshness of coats, dull eyes, unthrifty condition, and perverted appetite. Such areas are known as mineral deficiency areas. Studies of this subject have been made by Welch

(1924) in Montana, by Schmidt *(1924)* in Texas, by Eckles, Becker, and Palmer *(1926)* in Minnesota, and by Hart and co-workers *(1927)* in Wisconsin. The trouble has also been reported in West Virginia and Alabama by Halverson and Nixon *(1924)*, in Florida by Bitting *(1894)*, in Pennsylvania by Pearson *(1898)*, and in various other states.

Similar areas have been reported in other countries. Von Gohren *(1861)* and Nessler *(1873)* reported such trouble in Germany, Aston *(1905)* in New Zealand, Murphy *(1917)* in Victoria, Theiler *(1920)* and associates *(1924)* in South Africa, Tuff *(1924)* in Norway, and Marcq *(1925)* in the Belgian Congo. This condition is no doubt much more widespread than these scattered reports indicate.

Very little experimental work has been reported concerning the effects of rations low in calcium and phosphorus upon growing dairy animals. Eckles and Swett *(1918)* found that a dairy heifer when fed a ration low in calcium made normal growth up to eighteen months of age, but that she then became stiff in her joints and could get up only with the greatest difficulty. Rose *(1912)* found that dairy cows receiving a low phosphorus ration for four weeks became stiff in the joints and decreased in milk flow. Salmon and Eaton *(1925)* were unable to increase the growth of heifers by the addition of bonemeal to the ration.

Forbes and co-workers *(1922)* after extensive mineral balance experiments with dairy cows in milk flow *(1916, 1917, 1918, 1922a)* concluded that the calcium metabolism of the milk cow while on winter feeds is characterized by rapid loss from the body during the early part of lactation, changing to retention late in lactation, and by continued retention during the dry period, with most rapid storage at the end of the period of gestation. Hart and associates *(1921, 1922, 1923, 1923a)* have found that green plant tissue contains the factor which assists in assimilation of minerals by the dairy cow. The same authors *(1924)* also found that the ultra-violet rays have a beneficial influence upon the assimilation of calcium and phosphorus by a milking goat.

METHODS EMPLOYED IN THE EXPERIMENT

The object of the experiment was to determine the effect upon growing dairy heifers of feeding rations which contained different amounts of calcium and phosphorus.

In order to make such a study 32 grade Holstein heifer calves were divided into 4 groups of 8 calves each. Each group was fed a ration as similar to the other rations in its digestible crude protein and total nutrient content as it was practical to obtain. All were fed according to the Morrison Feeding Standard for dairy heifers. The chief difference between the rations fed was in the calcium and phosphorus content.

Group I, the check group, during the trial was fed, as far as could be ascertained before the beginning of the experiment, a normal ration. This ration was selected as typical of those fed under practi-

cal farm conditions. Since this ration contained a legume hay as one-half of the roughage and a typical grain mixture which has been fed widely without apparent bad results, it was assumed that its calcium and phosphorus content was sufficient.

Group II was fed a ration very much lower in its calcium content but otherwise similar to that of Group I in its nutritive value. Group II was designated as the low-calcium group.

Group III, designated as the low-phosphorus group, was fed a ration similar in its nutritive value to that fed to Group I with the exception that it was much lower in its phosphorus content.

Group IV, designated as the low-calcium-low-phosphorus group, was fed a ration low in both calcium and phosphorus as compared to the ration fed to Group I, but otherwise similar in its nutritive value.

The animals were handled and cared for in the same manner throughout the experiment, in order that, as far as could be ascertained, the rations consumed would constitute the only difference between the 4 groups. There was, of course, some difference in the individuality of the calves, but this probably was not pronounced, since the groups were quite uniform at the beginning of the experiment.

In order to study the difference between the rations, the heifers were weighed and the height at their withers was measured at weekly intervals so that the growth of the animals could be ascertained. The calves also were watched daily for all abnormalities, and notes were taken as to their general appearance, health, period of oestrum, unnatural cravings, or any other tendencies.

Analyses were made also of the blood for calcium and inorganic phosphorus at three-month intervals in order to ascertain the effects of the ration upon the calcium and inorganic phosphorus content of the blood.

To ascertain the effects upon the internal organs and upon the bones of the animals, two animals from each group were slaughtered at the end of 8 months, two at the end of 13 months, two at the end of 19 months, and two at the end of 25 months. At the time of slaughter the internal appearance of the animals was noted, and weights were taken of the different internal organs. Samples of the long bones also were obtained for analysis and for determination of breaking strength.

Throughout the experiment Group I was considered as normal, and the other groups were compared to it.

DESCRIPTION OF ANIMALS USED

Thirty-two grade Holstein calves from 2 to 4 weeks in age were obtained from northern Pennsylvania, arriving in the coldest part of the winter. Most of them took sick and several died. Replacements in most cases from other shipments from the same source were made as soon as possible. Many of the calves, however, were slow to recover, and it was necessary to feed them milk much longer than had been planned. No knowledge of the ancestry of the animals was at hand. They were well marked, only two of them showing any Jersey

characteristics. Since all came from the same locality it may be assumed that they probably had somewhat the same general ancestry. They were under the normal size as given by Eckles *(1920)* in weight but not in height at withers.

The calves were divided into 4 groups as nearly as possible the same as to age, weight, and height at withers. In certain groups there were more replacements than in others, and hence the difference in size became somewhat greater; but in spite of such replacements the 4 groups were fairly uniform at the beginning of the experiment. Table 1 gives the age, the time started on experiment, and the initial weight and height at withers for the various calves.

Housing and Care of the Animals

The animals were housed in a well-lighted and ventilated experimental barn. Each animal was kept in an individual pen so that it

TABLE 1.—*Date of Birth, Date of Starting on Experiment, Weight, and Height of Animals Used in the Experiment*

Number of Calf	Date Born	Date Started on Experiment*	Weight	Height at Withers
GROUP I. NORMAL GROUP				
			(pounds)	*(cms.)*
E-1	1-24-26	2-22-26	100	75.5
E-2	1-28-26	2-22-26	98	73.3
E-3	2-3-26	2-22-26	87	73.5
E-4	2-1-26	2-22-26	85	74.0
E-5	1-28-26	2-22-26	79	73.4
E-6	2-2-26	2-22-26	75	71.6
E-7	2-3-26	2-22-26	69	68.5
E-8	2-2-26	2-22-26	64	69.0
Average			82.1	72.3
GROUP II. LOW-CALCIUM GROUP				
E-9	1-25-26	2-22-26	100	78.7
E-10	4-10-26	4-20-26	80	71.0
E-11	2-5-26	2-22-26	87	72.5
E-12	2-5-26	2-22-26	85	72.8
E-13	2-2-26	2-22-26	76	70.3
E-14	2-4-26	2-22-26	75	71.6
E-15	3-15-26	4-1-26	79	68.5
E-16	2-8-26	2-22-26	67	74.4
Average			81.1	72.3
GROUP III. LOW-PHOSPHORUS GROUP				
E-17	1-23-26	2-22-26	109	75.5
E-18	2-6-26	2-22-26	96	75.0
E-19	1-27-26	2-22-26	90	72.9
E-20	1-31-26	2-22-26	82	74.2
E-21	1-28-26	2-22-26	81	75.0
E-22	2-4-26	2-22-26	74	70.3
E-23	2-1-26	2-22-26	70	72.3
E-24	3-15-26	4-1-26	82	72.0
Average			85.5	73.4
GROUP IV. LOW-CALCIUM-LOW-PHOSPHORUS GROUP				
E-25	1-23-26	2-22-26	109	80.5
E-26	2-24-26	3-1-26	110	74.0
E-27	2-5-26	2-22-26	90	73.9
E-28	1-30-26	2-22-26	84	71.1
E-29	1-31-26	2-22-26	80	71.3
E-30	4-10-26	4-15-26	90	73.0
E-31	2-1-26	2-22-26	69	71.5
E-32	3-15-26	4-1-26	89	75.0
Average			90.1	73.8

*The calves were put on the various rations outlined at about four months of age.

could be fed separately. The pens were about 3½ by 4 feet in size. When the calves were 13 months old, after one-half their number had been slaughtered the pens were increased in size to about 5 by 6 feet. The animals remained in these pens all the time except once a week, when they were removed to be weighed and measured. This was done in the same barn. They were removed from the barn but once every six months, when they were being photographed.

Although the barn had an abundance of light, the ultra-violet rays were not a factor to be considered, since the windows were kept closed. Hess and associates *(1922)* have shown that common window glass will allow no wave lengths shorter than 334 millimicrons to pass through and so will filter out all of the light that is beneficial to calcium and phosphorus assimilation. Gullickson and Eckles *(1927)*, however, have found that dairy heifers can be grown satisfactorily away from the light even on rations not very high in calcium.

Exercise. The animals were given no exercise except what they were able to obtain in their pens and when they were weighed each week. It was noted that many of them played a great deal in their pens, thus getting considerable exercise.

Bedding. The pens were bedded with shavings so that no nutrients were obtained from that source.

Weighing and Measuring. Weight of the animals and measurements at the height of the withers were taken at weekly intervals. These weights and measurements were averaged monthly.

Breeding. Since it was the object to study the effects of the rations on growing heifers, none of the animals was bred, in order that the factor of gestation might not enter into the problem. The times of oestrum, however, were observed in order to determine the effect of the rations upon the time of the first signs of oestrum and the regularity thereafter.

Salting. Once a week each heifer was given all the salt desired The salt was carefully weighed and placed before each animal and left there for about one hour, when it was removed and again weighed. In this way the amount consumed was ascertained.

The amount consumed varied from month to month, but the heifers on the restricted ration did not appear to crave the salt and did not consume any more than did those fed the normal ration. It was planned to restrict all calves to the same amount of salt as was consumed by the ones on the normal ration, but since the other calves did not seem to crave the salt, restriction was not found necessary.

Water. Water was given twice a day in buckets. Three times per month—on the fifth, fifteenth, and twenty-fifth days of the month —weights were taken of the amount consumed and used as the average daily consumption of water. There was considerable variation in the consumption of water by individual animals. Some individuals would average as much as 90 pounds per day for certain months, while others would average as low as 20 pounds for the same month. Some were consistently heavy drinkers while others were just as consistently light drinkers. No apparent difference could be noted,

however, between heavy and light drinkers. Neither could it be noted that any one group had a larger number of heavy drinkers than any other group.

When the average daily consumption of water per animal in each group was considered, very little difference could be noted in the amount consumed. Group II, the low-calcium group, consumed on the average about 2½ pounds more per day than the normal-fed group, and Group IV, the low-calcium-low-phosphorus group, consumed a little over one-half pound more than did the calves receiving the normal ration. Group III, the low-phosphorus group, on the other hand, consumed almost a pound less per day than the normal-fed group.

TABLE 2.—*Average Composition of Feeds Used*

Feed	Water	Ash	Crude Protein	Carbohydrates		Ether Extract
				Cr. Fiber	N.F.E.	
	(percent)	*(percent)*	*(percent)*	*(percent)*	*(percent)*	*(percent)*
Cornmeal	9.96	1.54	9.44	2.78	72.03	4.25
Oats (ground)	7.76	3.76	16.87	12.55	61.52	3.54
Linseed oilmeal	8.07	5.15	35.92	7.17	37.64	6.05
Soy beans	6.70	4.82	39.70	4.26	24.84	19.58
Beet pulp	7.66	3.21	10.25	19.07	59.12	0.69
Polished rice	10.91	0.52	8.94	0.47	80.77	0.39
Wheat gluten	7.76	0.97	80.22	0.66	9.94	0.45
Washed bran	7.40	1.50	14.70	13.12	61.15	2.13
Alfalfa hay	5.14	5.64	11.54	32.28	43.98	1.42
Timothy hay	5.33	4.70	5.85	30.96	51.36	1.80

The water was analyzed for calcium and phosphorus and found to contain 2.96 parts of calcium per million parts of water and only a slight trace of phosphorus. The amount of these elements obtained from the water therefore was very small. The amount of calcium received per month through the water would be about 12 grams, which would amount to but 0.4 of a gram per day.

Methods of Feeding

Early Feeding. Since the calves were received in a weakened condition, many had to be fed whole milk and all had to be fed skimmilk for a much longer period than had been planned. It was impossible to make them consume the experimental ration for some time and so they were started on whole oats and later fed for a short period on a ration of equal parts of oats, corn, and linseed oilmeal. They were put on the experimental ration at 4 months of age, when they were growing normally. They were not weaned from skimmilk until they were five months of age; some individuals were fed skimmilk until they were six months old.

Analysis of Rations. Each animal was fed individually throughout the experiment. Necessary changes in the feeding were made at two-week intervals, and all refuse was carefully recorded daily. In this way a complete record was kept of all the feed consumed by each individual. A year's supply of feed was purchased at a time so that variations in the feeds would be kept at a minimum. These feeds were carefully sampled and analyzed each year. The results as given in Table 2 are the average analyses of the feeds for the two years of the experiment.

108507

Rations. The rations used throughout the experiment are given in Table 3.

The rations numbered from I to IV were fed during the first year of the experiment and were fed to Groups I to IV, respectively. They were calculated for a normal 6-months old heifer and were fed so that each was receiving its requirements according to the Morrison standard.

When the heifers were a year old the rations were changed. This was made necessary because the requirements change slightly as the animals grow older, and, in the case of Rations III and IV, because analysis of the phosphorus content of the washed bran showed that only about one-third of the phosphorus was being removed by the method used in washing. Hart, McCollum, and Fuller *(1909)* had been able to wash practically all of the phosphorus from bran by allowing whole bran to soak over night in warm water, when an acid fermentation resulted. The bran subsequently was thoroughly washed with water and dried. The bran washed in their work contained only 0.11 percent of phosphorus as compared to 1.51 percent for whole bran. The results in the present experiment showed that the bran washed in the manner described above contained on the average 0.94 percent of phosphorus, and as it was being fed for its supposedly low phosphorus content it was at once omitted from the ration, and beet pulp was substituted.

TABLE 3.—*Average Daily Ration Fed during Experiment*

Feed	Ration Number							
	I	II	III	IV	Ia	IIa	IIIa	IVa
Alfalfa hay *(pounds)*	3	...	3	...	4	...	4	...
Timothy hay "	3	6	3	6	4	8	4	8
Cornmeal "	1¼	1	...	...	3	2	...	...
Ground oats "	1¼	1	...	...	3	2	...	...
Linseed oilmeal "	¾	...	...	...	...	...	...	...
Ground soybeans "	...	1½	...	...	...	1¾	...	...
Polished rice "	...	...	2	1½	...	...	3	3
Washed bran "	...	...	1½	2	...	...	...	...
Wheat gluten "	...	...	¼	½	...	...	½	1
Beet pulp "	...	...	...	...	...	...	2	1½

Rations Ia to IVa were fed during the second year of the experiment and were fed to Groups I to IV respectively. They were calculated for normal 12-months old heifers and differed only from Rations I to IV in amounts, with the exception that linseed oilmeal was dropped out of Ration I to form Ration Ia, and beet pulp was substituted for washed bran in Rations III and IV to form Rations IIIa and IVa.

The average analyses as shown in Table 2 were converted to the digestible basis by the digestibility of American feed stuffs as given by Henry and Morrison *(1923)* whenever possible; otherwise the digestibility of some closely related feed was used. In this way the average amount of digestible protein and digestible nutrients consumed by each group was ascertained as is shown in Table 4. This table and many of those following are divided into periods, from the beginning of the experiment to 8 months, from 8 months to 13

months, from 13 months to 19 months, and from 19 months to 25 months to correspond to the time of slaughtering the animals, as studies and comparisons can more easily be made in that manner.

Table 4 shows that, whereas there is considerable difference in the total amount of digestible crude protein and total digestible nutrients consumed per day, on the live weight basis there is very little difference. The normal group consumed slightly less digestible protein than did the other groups. There was very little difference between the amount of digestible nutrients consumed by the different groups per 100 pounds of live weight. This would indicate that, as far as nutritive value was concerned, the animals should make similar growth.

Calcium and Phosphorus Content of the Ration. The different feeds were analyzed for their ash and calcium and phosphorus content, with the results as shown in Table 5.

The feeds, as a general rule, analyzed just a little higher in calcium than has been found at other stations. This was especially true of the calcium content of the alfalfa and timothy hay. Both contained more than twice as much calcium as was found by Forbes and coworkers *(1913)*. Both also were lower in phosphorus than was found by Forbes. This was particularly true of the alfalfa hay, of second-

TABLE 4.—*Average Daily Amount of Digestible Crude Protein and Total Digestible Nutrients Consumed by the Animals in Each Group, and Average Daily Amount Consumed Per 100 Pounds of Live Weight of the Animals, by Periods*

Period Ending when Animals Were at Age of	Average Weight	Pounds Protein Consumed per Day	Pounds Protein Consumed Daily per 100 Pounds Live Weight	Pounds Total Digestible Nutrients Consumed per Day	Pounds Total Digestible Nutrients Consumed Daily per 100 Pounds Live Weight
GROUP I. NORMAL GROUP					
8 mos.	196	0.67	0.34	3.86	1.97
13 mos.	408	0.91	0.22	7.09	1.74
19 mos.	646	0.91	0.14	9.74	1.51
25 mos.	880	1.07	0.12	10.82	1.23
GROUP II. LOW-CALCIUM GROUP					
8 mos.	184	0.66	0.36	3.84	2.09
13 mos.	381	1.11	0.29	7.61	2.00
19 mos.	585	1.12	0.19	8.67	1.48
25 mos.	750	1.26	0.17	10.09	1.34
GROUP III. LOW-PHOSPHORUS GROUP					
8 mos.	192	0.63	0.33	3.79	1.94
13 mos.	395	0.89	0.23	6.90	1.75
19 mos.	617	1.09	0.18	9.40	1.54
25 mos.	833	1.27	0.14	10.43	1.25
Group IV. LOW-CALCIUM-LOW-PHOSPHORUS GROUP					
8 mos.	180	0.62	0.34	3.55	1.97
13 mos.	366	0.93	0.25	6.80	1.86
19 mos.	570	1.10	0.19	8.36	1.47
25 mos.	731	1.28	0.17	9.37	1.28

TABLE 5.—*Average Amount of Ash, Calcium, and Phosphorus Found in 100 Pounds of Feed Used in Experiment*

Feed	Pounds Ash	Pounds CaO	Pounds Calcium	Pounds P_2O_5	Pounds Phosphorus
Cornmeal	1.34	0.038	0.027	0.69	0.301
Oats (ground) ...	3.37	0.130	0.093	0.88	0.383
Linseed oilmeal .	5.72	0.530	0.379	1.90	0.828
Ground soybeans	4.51	0.290	0.208	1.36	0.593
Beet pulp	3.56	1.100	0.788	0.20	0.087
Polished rice	0.55	0.015	0.011	0.23	0.100
Wheat gluten ...	1.01	0.100	0.072	0.73	0.315
Washed bran ...	5.45	0.218	0.156	2.16	0.942
Alfalfa hay	8.53	3.300	2.369	0.35	0.159
Timothy hay	4.63	0.530	0.379	0.30	0.131

cut alfalfa obtained from Michigan. Reed and Huffman *(1928)* have found that the alfalfa hay from parts of Michigan is quite high in calcium and low in phosphorus—a possible explanation of results. The fact that the analyses varied from the average has caused the rations to be higher in calcium and the normal phosphorus rations to be lower in phosphorus than was desired. The fact also that the phosphorus was not washed from the bran caused Rations III and IV to be much higher in phosphorus than was desired.

Table 6 shows the total amount of calcium and phosphorus in each of the rations used. It also shows the amount of each mineral per hundredweight of the animals and per 100 grams of the ration, and also the ratio between the phosphorus and calcium in each ration. The rations vary from 2.78 to 11.56 grams of calcium per 100 pounds of live weight and from 0.249 to 0.936 grams of calcium per 100 grams of the ration.

In phosphorus the rations vary from 1.43 to 3.86 grams per 100 pounds of live weight and from 0.131 to 0.298 grams per 100 grams of the ration. The ratio between the phosphorus and calcium varies from 1 :0.9 to 1 :7.2.

The average amount of calcium and phosphorus consumed by the calves in each group per day and the amount consumed per 100 pounds of the animal are shown in Table 7.

Table 7 shows that during the first period all of the animals were fed rations containing considerably more of both calcium and phosphorus in relation to their weight than they received during later periods. This was due largely to the milk, which was fed in large amounts during the first period. Toward the latter part of the period, of course, the ration contained much less of these elements. In the ration of Groups I and III the calcium was supplied in fairly large amounts at all times, due largely to the alfalfa hay fed. The calcium in the rations fed to Groups II and IV, however, was much restricted in relation to the weight of the animals.

During the first two periods the phosphorus was supplied fairly well in the rations of all 4 groups. It, however, was not extremely high in any of the rations. During the last two periods the rations of Groups III and IV were quite low in phosphorus. The ration of

Group I was quite low in its content of phosphorus during the last period, illustrating the fact that rations which are thought normal may sometimes be very close to the lower limit of the requirements of the animals.

Discussion of the Rations Fed

Amount of Phosphorus and Calcium Fed. While there is no definite knowledge as to the correct amount of calcium and phosphorus to include in a ration for a dairy animal, several investigators have stated what they believed to be the requirements for such animals, while others have calculated the amount retained by such animals.

Kellner *(1907)* computed the calcium and phosphorus retention of growing calves as 21 grams of CaO and 19 grams of P_2O_5 per day during the first year, which amounts to about 15 grams of calcium and 8.3 grams of phosphorus per day. He states that the feed should contain from 40 to 60 grams of each per day.

Armsby *(1917)* computed from Lawes and Gilbert's analyses of the ash of the entire body of farm animals that during the first year, cattle gain a total of 5,609 grams of calcium and 2,972 grams of phosphorus. This is an average daily retention of 15.37 grams of calcium and 8.14 grams of phosphorus per animal. On a 100-pound basis, cattle during the first year require 3.2 grams of calcium and 1.7 grams of phosphorus daily in their bodies.

McCollum and co-workers *(1922)* have found that for rats a content of 0.641 grams of calcium per 100 grams of the ration is very near to the optimum concentration of this element. They *(1922a)* also found that the optimum amount of phosphorus for growing rats is not less than 0.4146 percent. It may be considerably higher.

If Kellner's and Armsby's figures, as given above, which check very closely with each other and which apply to the conditions in the present experiment, are considered, it can be seen by Tables 6 and 7 that Group I was being fed ample calcium and sufficient phosphorus, if there is a fairly high percentage of retention, throughout the entire experiment, although the amount of phosphorus during the latter part of the experiment was dangerously near the lower limits of the requirements. Group II was fed just about the amount of calcium

TABLE 6.—*Total Amount of Calcium and of Phosphorus, Amount of Each per Hundredweight of the Animal and per 100 Grams of the Ration, and Ratio between Phosphorus and Calcium in the Various Rations Indicated in Table 3*

Ration Number	Grams Calcium in Daily Ration	Grams Ca per cwt. of Animal	Grams Ca per 100 Grams of Ration	Grams Phosphorus in Daily Ration	Grams P per cwt. of Animal	Grams P per 100 Grams of Ration	Ratio between P and Ca
I	39.32	11.23	0.936	10.53	3.01	0.251	1:3.7
II	12.34	3.53	0.286	10.72	3.06	0.248	1:1.2
III	40.47	11.56	0.914	11.54	3.30	0.261	1:3.5
IV	12.05	3.44	0.265	13.52	3.86	0.298	1:0.9
1a	51.42	9.18	0.809	13.94	2.49	0.220	1:3.7
IIa	15.59	2.78	0.249	15.67	2.79	0.251	1:1
IIIa	57.25	10.23	0.934	8.03	1.43	0.131	1:7.2
IVa	19.69	3.51	0.321	8.15	1.45	0.133	1:2.4

that should be retained during the first year of the experiment and considerably less than is required for retention during the latter part of the experiment. The amount of phosphorus probably was ample throughout the entire experiment. Group III was fed an abundance of calcium and probably enough phosphorus during the first year, but during the second year the amount of phosphorus was considerably less than is required for retention. Group IV also was fed just about the amount of calcium that should be retained, and during the first year probably was fed sufficient phosphorus. During the last year, however, the phosphorus was considerably below the amount which is required for retention.

TABLE 7.—*Average Daily Amount of Calcium and of Phosphorus Consumed by the Animals in Each Group, and Average Daily Amount of Each Consumed per 100 Pounds of Live Weight of the Animals, by Periods*

Period Ending When Animals Were at Age of	Average Weight	Grams Calcium Consumed per Day	Grams Calcium Consumed per cwt. of Animal	Grams Phosphorus Consumed per Day	Grams Phosphorus Consumed per cwt. of Animal
GROUP I. NORMAL GROUP					
8 mos.	196	25.7	13.1	9.3	4.7
13 mos.	408	45.7	11.2	13.0	2.5
19 mos.	646	54.9	8.5	14.4	2.2
25 mos.	880	64.2	7.3	16.9	1.9
GROUP II. LOW-CALCIUM GROUP					
8 mos.	184	13.1	7.1	8.6	4.7
13 mos.	381	14.5	3.8	13.5	3.5
19 mos.	585	16.6	2.8	15.0	2.5
25 mos.	750	20.1	2.1	17.3	2.3
GROUP III. LOW-PHOSPHORUS GROUP					
8 mos.	192	24.7	12.9	9.2	4.8
13 mos.	395	44.8	11.3	13.5	3.4
19 mos.	617	60.8	9.8	8.5	1.2
25 mos.	833	71.3	8.5	10.0	1.2
GROUP IV. LOW-CALCIUM-LOW-PHOSPHORUS GROUP					
8 mos.	180	11.3	6.3	9.4	5.2
13 mos.	366	13.6	3.7	15.0	4.1
19 mos.	570	20.0	3.5	8.2	1.4
25 mos.	731	22.3	3.0	9.1	1.2

If the optimum requirements for calcium and phosphorus, as found by McCollum for rats as given above, is applied to the rations for dairy calves, it will be seen that Rations II, IV, IIa, and IVa are all below the optimum requirements for calcium, and that all of the rations are considerably below the optimum requirements for phosphorus.

The amount of phosphorus and calcium required in a ration depends largely upon the retention of these elements by the animal. It is of no use to feed a large amount of these elements if they are not retained. No definite results have been obtained as to the percentage of these elements which are retained in the body. It is now known that this depends upon several factors.

Ratio of Calcium and Phosphorus. That a proper ratio between the amount of calcium and phosphorus in a ration is important has been shown by several workers.

McCollum and co-workers *(1921a)* found that in the rat the profound disturbances in the deposition of lime salts in cartilage and bone and the changes in the cells of those tissues which give rise to rickets, may be produced by a disturbance in the diet of the optimal ratio between calcium and phosphorus. They stated that it would seem that in so far as calcium and phosphorus are concerned the proper ratio between the two is of vastly more importance in insuring normal calcification than the absolute amount of the elements themselves.

Haag and Palmer *(1928)* with rats obtained results which indicated that a more or less balanced condition of calcium, magnesium, and phosphorus salts in the ration is essential to normal growth and functioning.

Gullickson and Eckles *(1927)*, however, with growing dairy heifers did not notice any ill effects of feeding rations in which the phosphorus content almost invariably exceeded the calcium content—most of the time by nearly two to one.

The rations under study varied greatly in the ratio between calcium and phosphorus. Ration IIIa had a ratio of phosphorus to calcium of 1 to 7.2, while Ration IV had a ratio of 1 to 0.9. The others varied between these two extremes.

Factor Which Assists in the Assimilation of Calcium and Phosphorus. That there is a specific factor connected with the assimilation of calcium and phosphorus was first shown by Mellanby *(1919)*, but he associated it with vitamin A. McCollum, Simmonds, and Becker *(1922)* clearly demonstrated the existence of a vitamin distinct from vitamin A which regulates the metabolism of the bones. That this vitamin is carried in green plant tissues has been shown by Hart and associates *(1923a)*. They have shown that green plant tissue contains more of this vitamin than plant tissue exposed to long curing processes, and that alfalfa hay when fed as a supplement to grains and grain by-products may be so cured as to retain qualities of this vitamin sufficient to maintain liberal milking cows in positive calcium and phosphorus balance. Under practical conditions of curing hay in the windrow with exposure to air and light, the hay is not capable of maintaining calcium and phosphorus equilibrium in milking cows. Hart and associates *(1924)* also have shown that the ultra-violet rays have a beneficial influence upon the assimilation of calcium and phosphorus by milking goats.

In this experiment no attempt was made to control the effects of this factor. Alfalfa hay was fed to Groups I and III, but it was of such a nature that it is doubtful that very much of this factor was available. Sunlight likewise was not a factor, since the heifers were kept indoors continuously, and any sunlight reaching them first passed through the window glass.

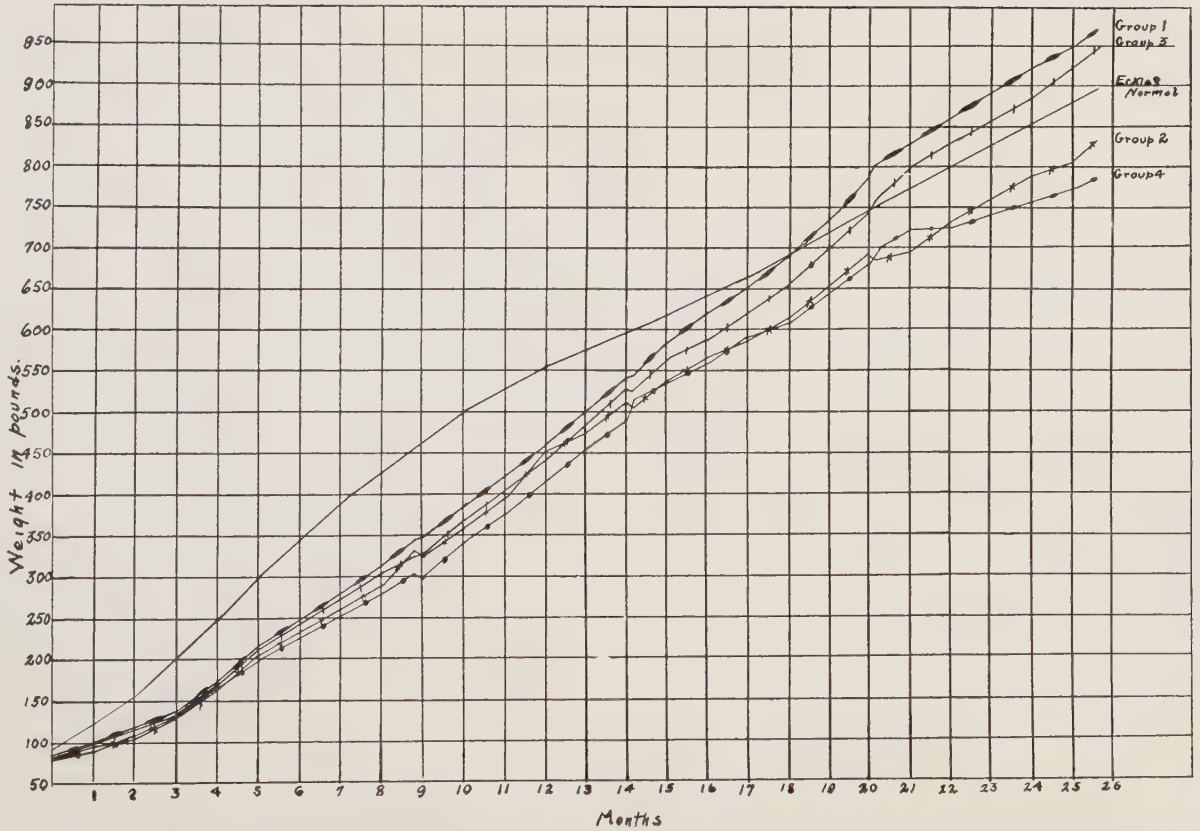


FIGURE 1.—Gain in Weight of the Four Groups of Animals as Compared to Each Other and to Eckles' Normal

RESULTS OF THE EXPERIMENT

Effect of Rations on Growth and Development of the Animals

Growth. The gain in weight and in height at withers is shown by Figures 1 and 2. The average monthly gains are shown by periods in Tables 8 and 9, where they are also converted to a percentage basis, using the normal-fed group as the basis of comparison.

It will be noted that during the first year none of the groups averaged as large as the figures given by Eckles *(1920)* for the normal purebred Holstein. The animals may not have been of as large a strain as those used by Eckles, but more probably the difference was due to the start which they received. As stated before, the calves when quite young were shipped a distance of several hundred miles

TABLE 8.—*Average Monthly Gain in Weight of Animals in the Various Groups, by Periods; Expressed also as Percentage of the Normal Group*

Period Ending When Animals Were at Age of	Average Monthly Gain in Weight of Group I (Normal)	Average Monthly Gain in Weight of Group II	Percent of Normal Group	Average Monthly Gain in Weight of Group III	Percent of Normal Group	Average Monthly Gain in Weight of Group IV	Percent of Normal Group
	(pounds)	*(pounds)*		*(pounds)*		*(pounds)*	
8 mos.	27.75	25.55	92.1	27.47	99.0	24.81	89.4
13 mos.	38.93	37.77	97.0	37.36	96.0	34.94	89.7
19 mos.	35.76	31.35	87.6	32.60	91.4	32.73	91.5
25 mos.	31.36	23.92	76.3	33.93	108.2	17.17	54.8

in the coldest part of the winter and many of them had a long sick period before they were able to start normal growth. Beginning when they were about 13 months of age the animals in all groups made very good gains. Those in Groups I and III passed the Eckles normal growth curve both in weight and in height at withers and at the end of the experiment averaged more than 50 pounds in weight over those used to establish the Eckles normal, and were also considerably above them in height at withers.

The animals in Groups II and IV, however, failed by more than 50 pounds to reach the size of the Eckles normal in weight and were also below them in height at withers. The animals in all of the groups were still growing at the end of the experiment. The rate of gain, however, was considerably slower than at first.

It will be seen that the animals in Group I in most cases grew faster than the animals in the other groups, although the animals in Group III gained almost as well as did the normal-fed group, especially in weight. They did not seem to gain as well, however, in height at withers, especially during the last periods.

The animals in Groups II and IV grew almost as well as the animals in the normal-fed group during the first two periods, but during the last two periods they failed to gain as rapidly either in weight or in height at withers. At the end of the experiment they averaged

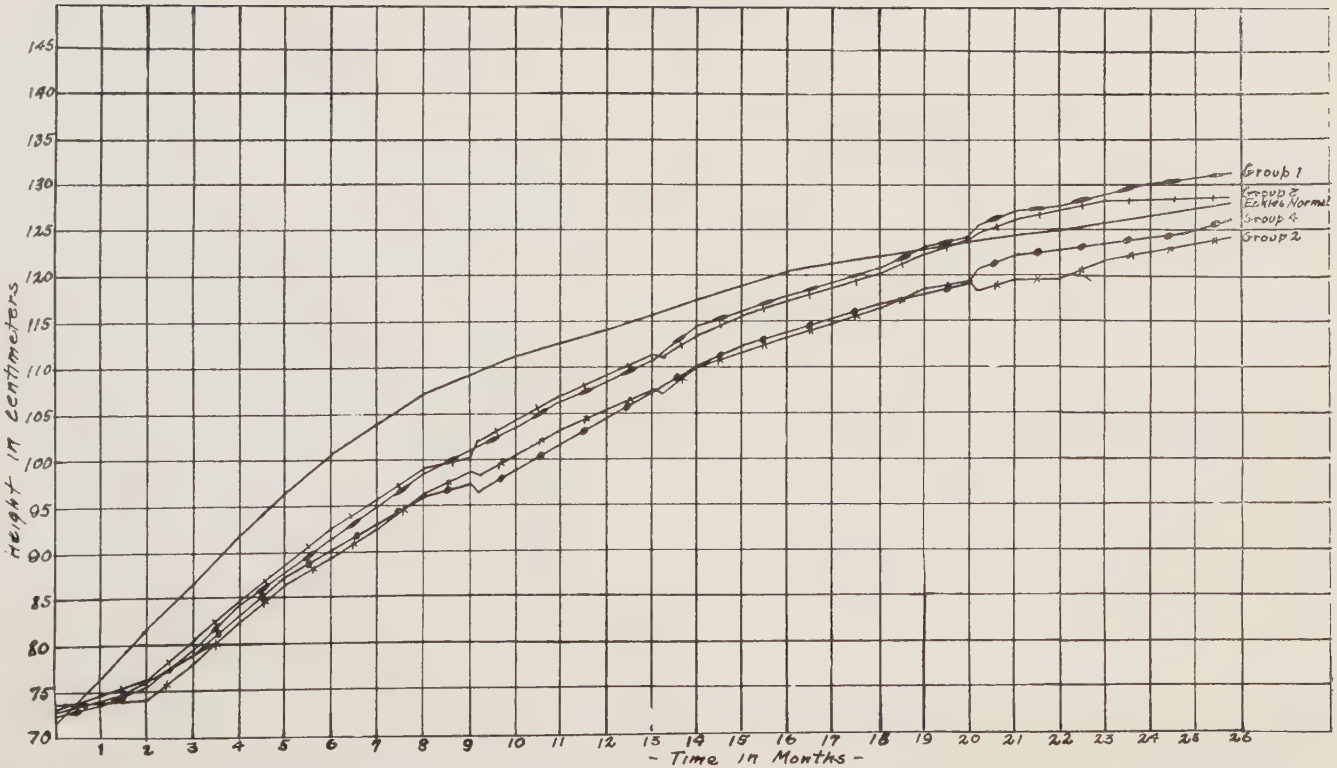


FIGURE 2.—Gain in Height at Withers of the Four Groups of Animals as Compared to Each Other and to Eckles' Normal

more than 100 pounds less in weight and more than 5 centimeters (2 inches) less in height at withers than the animals fed the normal ration.

Discussion of Results. It would seem that the slower growth made by the animals in Groups II and IV as compared to those in Groups I and III must be due to the lower calcium content of the ration. It will be noted that these two groups (II and IV) were both low in calcium throughout the experiment. Group IV was low also in phosphorus during the last two periods. However, the animals in Group III also were low in phosphorus during the same two

TABLE 9.—*Average Monthly Gains in Height at Withers of Animals in the Various Groups; Expressed also as Percentage of the Normal Group*

Period Ending When Animals Were at Age of	Average Monthly Gain in Height Group I (Normal)	Average Monthly Gain in Height of Group II	Percent of Normal Group	Average Monthly Gain in Height of Group III	Percent of Normal Group	Average Monthly Gain in Height of Group IV	Percent of Normal Group
	(cms.)	*(cms.)*		*(cms.)*		*(cms.)*	
8 mos.	3.31	2.83	85.5	3.23	97.6	2.93	88.5
13 mos.	2.45	2.30	93.8	2.70	110.2	2.27	92.6
19 mos.	1.94	1.84	94.8	1.74	89.5	1.75	90.2
25 mos.	1.00	0.74	74.0	0.85	85.0	0.83	83.0

periods but still made gains almost equal to normal for some time. Table 3 shows that the animals in both Groups II and IV consumed slightly more digestible crude protein per hundredweight of the animals and per pound of gain than did those in Groups I and III. The difference in growth therefore must have been due to some factor other than protein and total nutrients. It is possible that the greater growth may have been due to some factor contained in the alfalfa hay which was included in the rations of Groups I and III and not in those of Groups II and IV. However, the only great difference as far as could be noted by chemical analyses was in the calcium content.

It has been found by several investigators that animals will still continue to gain in weight and especially in height at withers under adverse conditions as to nutrition. Eckles *(1915)* found that deficient rations fed to growing heifers restricted gain in weight more than in height at withers. This same result was found by Reed, Fitch, and Cave *(1924)* and by Davis and co-workers *(1922)*. It has been shown by Trowbridge and co-workers *(1915, 1918)* and by Moulton and co-workers *(1918)* that young steers maintained at constant weight even on a sub-normal plane of nutrition continued to grow in height and in width of skeleton. They found that although the scantily fed steers grew less rapidly in all respects, they attained the same height at maturity as a group of full-fed steers. They tended to recover it by making more rapid gains when put on full feed and by continuing to grow for a longer period of time.

Investigators have not found, however, that rations low in calcium or low in phosphorus retard growth. Eckles and Swett *(1918)* found that the heifer fed a low-calcium ration continued to grow just as well as one which was being fed normally. The heifer at last became stiff and had difficulty in getting up and walking but gained normally up until this time. Similar results were obtained by Aron and Sebauer *(1908)* with dogs; by Maynard and co-workers *(1925)*, Bohstedt *(1926)*, and other investigators with pigs which were fed rations low in calcium; and by Hart and co-workers *(1909)* with pigs which were fed rations low in phosphorus. The animals in these cases continued to grow normally for some time, often up until the time of complete collapse.

On the other hand the cattle grown in the deficiency areas were almost invariably stunted. Eckles, Becker, and Palmer *(1926)* found that cattle grown in such areas in western Minnesota were decidedly stunted in size. Animals 4 years of age on some farms weigh less than 600 pounds as compared to a normal of 1,000 to 1,100 pounds for animals of similar size and breeding. Cattle were also reported stunted by Theiler and co-workers *(1924)*, Tuff *(1924)*, and by Hart and co-workers *(1927)*. These report that after bonemeal is fed, the cattle make rapid gains. The trouble in these areas is caused by the

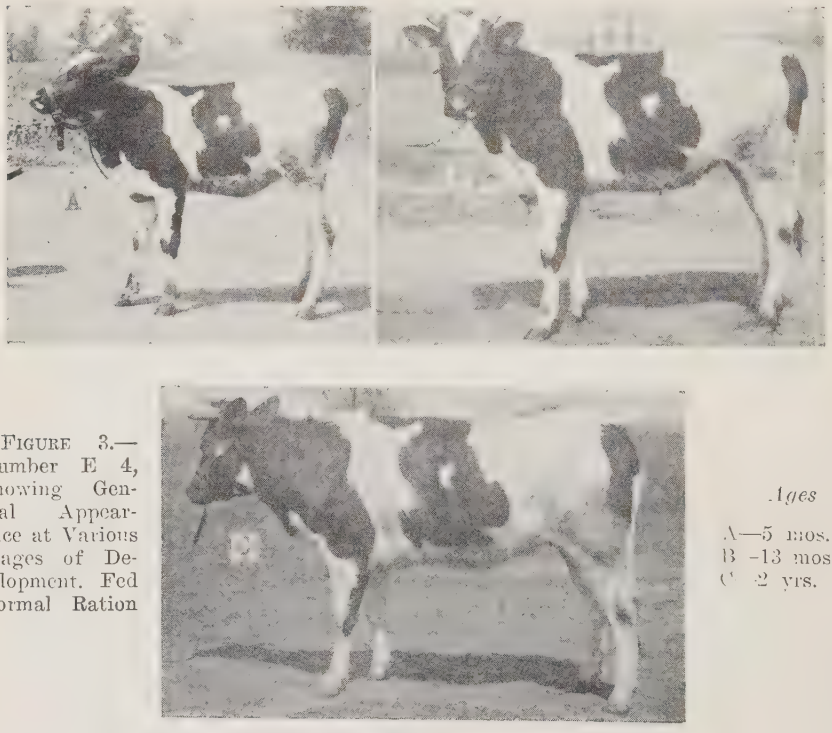


FIGURE 3.—Number E 4, Showing General Appearance at Various Stages of Development. Fed Normal Ration

Ages

A—5 mos.
B—13 mos.
C—2 yrs.

low phosphorus content of the feed produced. The stunted condition may be caused by the fact that the animal fed such rations does not consume enough for normal growth, but just as soon as the deficiency is replaced it begins to grow and to take on weight in the normal manner. This, however, was not true with the animals in the present experiment. All were fed according to their requirements as to digestible crude protein and digestible nutrients. These, however, did not appear to utilize their feed as well as did the normal-fed animals, since they consumed more digestible crude protein and digestible nutrients per pound of gain and per 100 pounds of live weight than did the normal-fed group.

The animals in Groups II, III, and IV continued to gain in weight practically as well as in height at withers in comparison with the animals in the normal-fed group.

In summary, dairy animals fed rations low in calcium or low in both calcium and phosphorus may continue to grow in weight and in height at withers for some time almost as well as dairy animals fed a normal ration, but over a period of two years they will not make the gains either in weight or height at withers as will animals fed a normal ration. The animals fed rations low in phosphorus, however, continued to grow almost as well as did the normal-fed group.

Physical Abnormalities. Figures 3 to 10 inclusive show pictures of representatives of each group at various stages of development.

All animals in Group I developed normally as far as general appearances were concerned. There were, of course, considerable differences in appearance, but no more than could be attributed to individuality.

All the animals in Group II developed normally as far as general appearances were concerned. They were not as large as the animals in Group I but otherwise appeared normal.

In Group III, No. E 20, the largest and fastest growing heifer in the group, became stiff in her joints in September, 1927, at 19 months of age, or 5 months after being put on Ration VIIa, which was very low in phosphorus. At the time the stiffness appeared she refused her feed for several days and seemed to be in considerable pain. She gradually recovered her appetite and continued to grow normally, but her legs never fully recovered from their stiffness and were slightly bent, as shown in Figure 11, the picture being taken in April, 1928. No. E 21, the mate of No. E 20, was a short-legged, sturdy type of heifer, and as far as could be noted her legs remained normal. Her back, however, did take on a slight sway at about the same age, whereas it had been straight when she was younger.

In Group IV, No. E 31 when a calf had a very severe case of scours and it was uncertain for some time whether she would recover. She gradually did recover but was never a thrifty, normal-looking or acting calf. In January and February, 1927, when she was about a year old, she became very nervous. Whenever anyone would enter her stall she would tremble violently. On January 25, 1927, and again on February 23, 1928, 4 months after she had received no milk and

was on the low-calcium-low-phosphorus ration, she suffered a fit-like spasm. She fell over in her stall, frothed at the mouth, became stiff, and lay prostrate. These symptoms were very similar to those noted when calves were fed milk or milk and grain as the sole diet, as reported by McCandlish *(1923)* and Reed and Huffman *(1925)*. The joints in her legs became swollen and her legs slightly bent. For several weeks she failed to gain in weight or height. However, she seemed to gain a little shortly before she was slaughtered, April 1, 1927. Probably the weakened condition of the calf, combined with the abnormal ration, brought on such trouble in this calf when more hardy calves, fed similar rations, seemed normal. If such was the case the amount of calcium in such a ration certainly must have been below the optimal requirements in calcium for such animals.

The other calves on this ration seemed to grow normally, although at a slower rate than the normal-fed group, until about September, 1927, when No. E 28 developed a sway in the back. This calf, as shown in Figure 9, had a straight back when she was a calf but gradually developed a sway until at the time of her death, April, 1928, she was extremely sway-backed. This is shown in Figure 12. Her

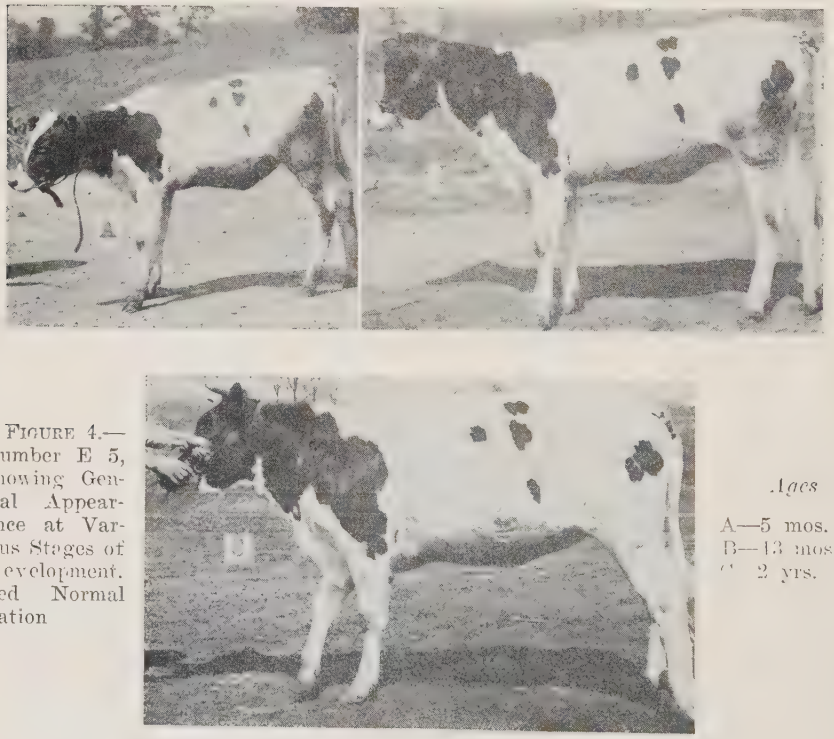


FIGURE 4.—Number E 5, Showing General Appearance at Various Stages of Development. Fed Normal Ration

Ages

A—5 mos.
B—13 mos.
C—2 yrs.

legs also were not very straight at this time. It is very doubtful if this heifer could have withstood the strain incident to pregnancy and lactation. She appeared to be getting worse as she grew older.

No. E 29, the mate of No. E 28, however, did not develop as abnormally in this respect. She was an extremely healthy heifer from the start and as a calf had a very straight, strong back. It could be noted, however, that her back had begun to sway toward the end of the experiment, but this was not nearly as evident as it was with No. E 28.

These observations suggest the possibility that swaybacks in mature animals are partially due to the ration which the heifers receive when growing, but that the individuality of an animal may partially overcome defects in the ration. A good strong individual may be able to withstand poorer rations than animals that are not as strong. This may be due to the greater storage of minerals that the stronger individual may have stored up when younger.

Abnormal Cravings. Most of the animals, even those fed the normal rations, chewed the wood in their stalls. This began at an early age, even before they were weaned from milk, and continued throughout the experiment. The animals in the normal group seemed just as abnormal in this regard as the others. Some of the animals ate a few shavings with which they were bedded, but this habit, too, seemed just as strong with the normally fed group as with the others.

Drinking Habits. The animals in Groups III and IV developed the habit toward the last of the experiment of grinding their teeth. They would stand for 15 to 20 minutes at a time grinding their teeth with a peculiar noise.

The animals in these two groups and also those in Group II developed the habit of lapping the water with their tongues in cold weather. Some of them would froth considerably at time of drinking. No. E 12 in Group II, Nos. E 20 and E 21 in Group III, and Nos. E 28, E 29, and E 30 in Group IV all showed this characteristic before they were slaughtered. No. E 28 in Group IV and No. E 20 in Group III were probably the worst in this habit.

When the teeth were examined at time of slaughter it was found that they had become so badly worn that some of them were down to the gums. The teeth of the animals in Groups II, III, and IV were all badly worn at the end of the experiment, although the teeth even of Group I were worn to some extent. They, however, were not worn nearly so badly as were those of the other groups. The same condition was noted by Reed and Huffman *(1928)* when they fed a lot of heifers raw rock phosphate in their ration. The teeth of these animals became sensitive to cold water when they were about 2½ years of age. An examination of their mouths revealed that the raw rock phosphate had brought about a softening of the teeth and in some instances the teeth were worn down to the gums.

TABLE 10.—*Age at First Signs of Oestrum, Total Number of Times Noted, and Regularity of Oestrum*

Number of Calf	Age at First Signs of Oestrum			Number of Times Noted	Regularity of Oestrum
	Years	Months	Days		
GROUP I. NORMAL GROUP					
E-3	1	1	11	10	regular
E-4	1	0	4	14	regular
E-5	1	1	22	13	regular
E-6	1	3	20	6	fairly regular
E-7	0	11	20	1	regular
Average	1	1	9	10.8*	
GROUP II. LOW-CALCIUM GROUP					
E-11	1	0	25	11	regular
E-12	1	9	23	5	irregular
E-13	1	0	11	5	very irregular
E-14	1	3	25	6	fairly regular
E-15	0	10	8	2	regular
Average	1	2	18	6.8*	
GROUP III. LOW-PHOSPHORUS GROUP					
E-19	1	2	29	12	regular
E-20	1	3	13	9	irregular
E-21	0	11	28	21	regular
E-22	1	1	13	10	regular
Average	1	1	28	13.0	
GROUP IV. LOW-CALCIUM-LOW-PHOSPHORUS GROUP					
E-27	1	3	16	7	fairly regular
E-28	1	4	20	10	irregular
E-29	1	4	5	10	irregular
E-30	1	1	7	3	irregular
Average	1	3	12	7.5	

*Average of first four animals only.

Effect of Rations upon the Oestrum of the Animals

Records were kept of the time the heifers in the various groups showed signs of oestrum. Of course some may have been missed but the attendant was on the watch at all times and recorded all that were noted. Table 10 gives the age of the heifers at the time of the first signs of oestrum, together with the total number of times of oestrum noted and the regularity of oestrum of the different heifers in the experiment.

Nos. E 1, E 2, E 8, E 9, E 10, E 16, E 17, E 18, E 23, E 24, E 25, E 26, E 31, and E 32 were slaughtered before they showed signs of oestrum.

It will be noted that the normal group averaged 1 year, 1 month, and 19 days of age at the time of the first sign of oestrum. They varied from 11 months and 20 days to 1 year, 3 months, and 20 days. All were fairly regular in the period between signs of oestrum, and were observed showing signs of oestrum a total of 44 times.

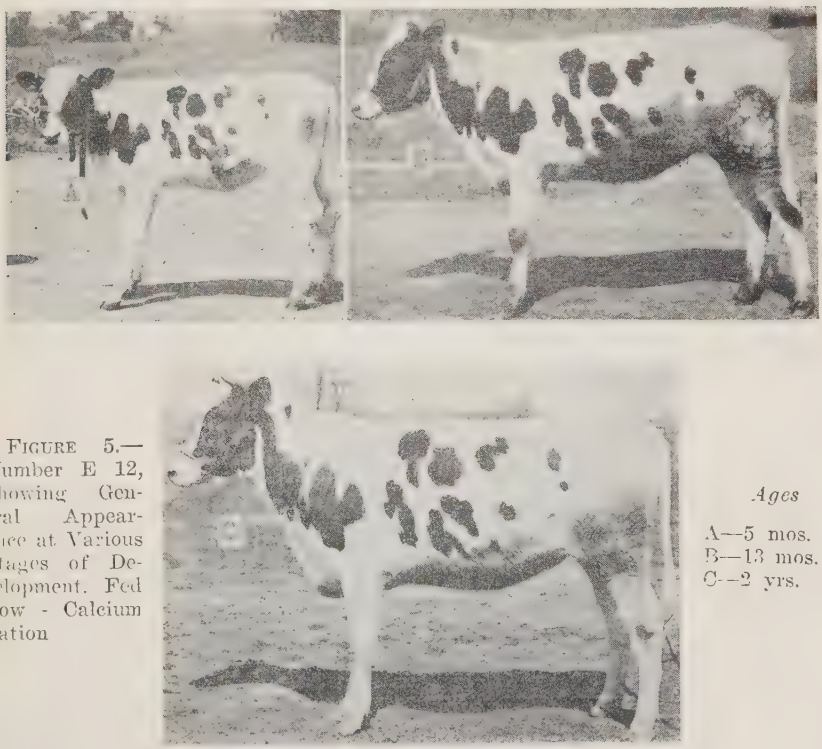
The animals in Group II averaged 1 year, 2 months, and 18 days of age when they first showed signs of oestrum. They were 1 month and 18 days older on the average than the normal group. No. E 12 did not show signs of oestrum until an advanced age, which was largely responsible for this difference. The animals were noted show-

ing signs of oestrum a total of 27 times, or 17 times less than Group I. As a group, the period between signs of oestrum was irregular.

The animals in Group III averaged 1 year, 1 month, and 28 days of age when they first showed signs of oestrum. This was only 19 days older than the average of the animals in the normal group. They were observed showing signs of oestrum a total of 52 times, or 8 times more than the animals in the normal group. They were fairly regular in period between times of oestrum. Since their ration was not greatly different from that of Group I in its calcium and phosphorus content up until the animals were a year old, very little difference in time of first signs of oestrum between the animals in this group and those in Group I would be expected.

The animals in Group IV averaged 1 year, 3 months, and 12 days when they first showed signs of oestrum. This was 2 months and 3 days older than the animals fed the normal ration. They were observed to show signs of oestrum a total of 30 times, or 14 times less than the group fed the normal ration. They were quite irregular in the period between times of oestrum.

Discussion of Results. The results indicate that the heifers in Groups I and III showed signs of oestrum when they were 1½ to 2 months younger than the heifers in Groups II and IV.



Ages

A—5 mos.
B—13 mos.
C—2 yrs.

FIGURE 5.—Number E 12, Showing General Appearance at Various Stages of Development. Fed Low - Calcium Ration

The heifers in Groups I and III also were much more regular in period between times of oestrum than were the heifers in the other two groups.

This is in agreement with results obtained by other investigators, as there is found evidence in literature which indicates that rations quite low in the minerals often cause serious disturbances in reproduction. Eckles, Becker, and Palmer *(1926)* found that in the deficient area in western Minnesota considerable trouble was experienced with breeding. On many farms the cows were not expected to produce a calf more than once in two years. Heifers often did not show signs of oestrum until two years of age. The average calf crop in the worst-affected districts, as observed after a dry season, was estimated at less than 50 percent of the normal. Tuff *(1924)* also found that in seasons of low rainfall the trouble incident to reproduction in the cattle in deficient areas of Norway was increased. The cattle seem to fail to ovulate. Meigs and Woodward *(1921)* also found difficulty in reproduction when cows were fed a ration low in calcium. Jordan, Hart, and Patten *(1906)*, studying the physiological effect of certain phosphorus compounds, found that when cows were fed rations very low in phosphorus they showed entire cessation of oestrum. Hart and co-workers *(1924)* in working with the rations derived from the oat and wheat plants found that normal reproduction would not

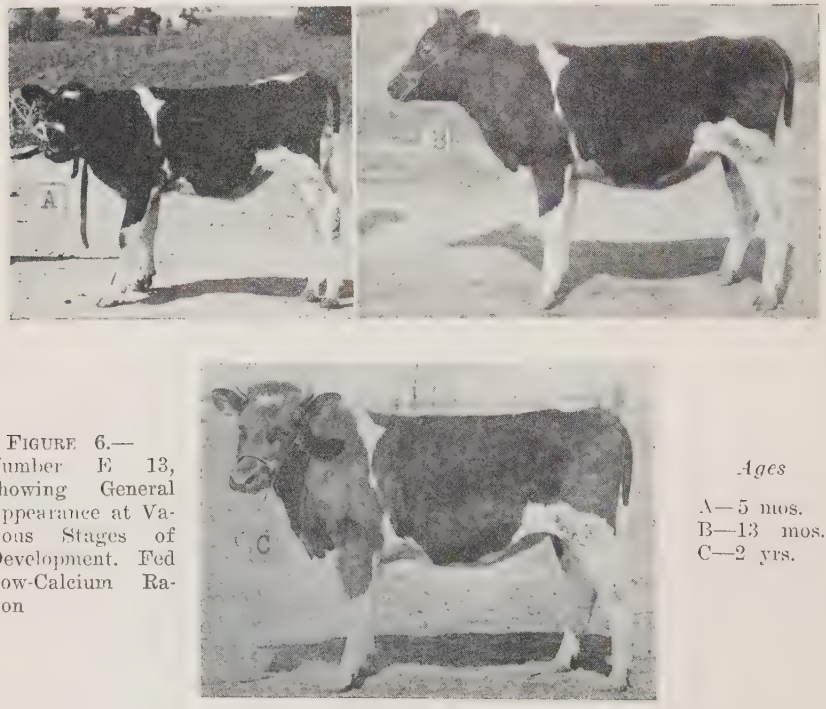


FIGURE 6.—Number E 13, Showing General Appearance at Various Stages of Development. Fed Low-Calcium Ration

Ages

A—5 mos.
B—13 mos.
C—2 yrs.

take place on account of lack of calcium. They state that 0.45 percent CaO in the ration is the least amount which can be fed in a ration to insure normal reproduction.

It can be seen by referring to Table 6 that the rations fed to the animals in Groups II and IV were slightly below the amount stated by Hart and co-workers to be the least amount of calcium that could be fed to insure normal reproduction. In their studies, however, the animals conceived but failed to drop normal offspring, or would abort. The animals in the present experiment were not bred.

Effect of the Rations upon the Calcium and Inorganic Phosphorus Content of the Blood

Since the blood carries the food nutrients to the parts of the body where they are needed, it would naturally be supposed that a lack of any required nutrient in the food would result in a lower concentration of this nutrient in the blood. This, however, is not always the case, since the blood is maintained fairly uniform in its constitution, even in time of low supply, by using some of the reserve supply which has been stored up in various parts of the body.

The calcium and inorganic phosphorus content of the blood, however, has been used for several years as a criterion in the demonstration of rickets in animals. Steenbock and co-workers *(1923)* used it as a criterion in the demonstration of the existence of a specific antirachitic vitamin. They were able to increase the calcium and inorganic phosphorus in the serum of dogs fed rachitic rations by the addition of cod-liver oil. They were also able to increase the concentration of calcium and inorganic phosphorus in the serum of chickens by the addition of cod-liver oil to a ration which otherwise caused leg weakness.

A study was therefore made of the blood of the animals in the present experiment to determine the effect of the rations upon its calcium and inorganic phosphorus content.

Analyses of Blood. Samples of blood were taken from each animal in the experiment at 9-month intervals and analyzed for calcium and inorganic phosphorus by the Briggs *(1922, 1924)* modification of the Bell and Doisy *(1920)* method.

The samples were taken from the jugular vein of the animals at the same hour each day in order that the samples might be as uniform as possible. After the first two times samples were taken on 3 consecutive days, and a composite of each day's sampling was used for the analyses.

Calcium. The average results obtained with the calcium analyses for each period are given in Table 11.

Table 11 shows that the rations had very little effect upon the calcium content of the blood. The blood of the calves fed the rations low in calcium had just as much calcium in it as the blood of the animals fed rations rich in calcium. Possibly if the calcium content of the rations had been somewhat lower, the blood would have been affected.

It can be noted also that in general, as the animal became older, there was a slight diminution in the calcium concentration of the blood.

Phosphorus. The average results obtained with the phosphorus analyses for each period are given in Table 12.

Table 12 indicates that the rations fed to animals exert a very profound influence upon the inorganic phosphorus content of the blood. When the ration fed contained ample phosphorus, as they all did in the first two periods of the trial, the inorganic phosphorus content of the blood remained normal. However, just as soon as the phosphorus in the feed was lowered, the inorganic phosphorus content of the blood also went down.

There appears some evidence that dairy animals are unable to keep the inorganic phosphorus content of their blood normal if they do not obtain sufficient phosphorus in the feed, even though they have ample storage in their bones. This is indicated in the experiment by the following facts: when the animals in Groups III and IV were fed a ration containing as much as or slightly more phosphorus than those in Groups I and II, they maintained the inorganic phosphorus content of their blood. On March 24, 1927, their rations were chang-

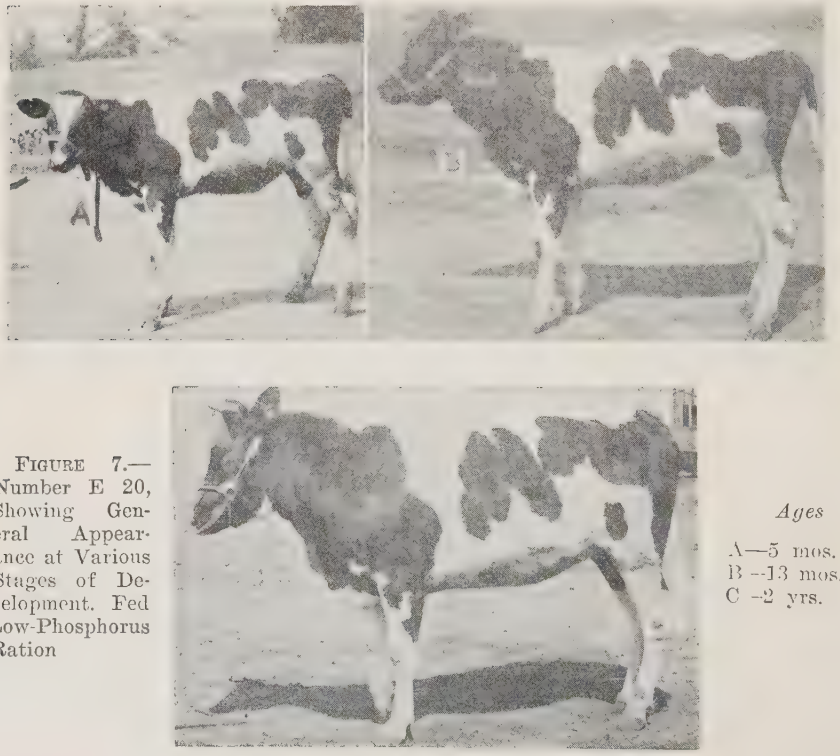


FIGURE 7.—Number E 20, Showing General Appearance at Various Stages of Development. Fed Low-Phosphorus Ration

Ages

A—5 mos.
B—13 mos.
C—2 yrs.

ed from Rations III and IV, which contained 3.4 gms. and 4.1 gms. respectively of phosphorus per hundredweight of the animals, to Rations IIIa and IVa, which contained 1.2 gms. and 1.4 gms. respectively of phosphorus per hundredweight of the animals. Samples of blood were taken beginning March 28, 1927, 4 days after the ration had been changed. In that short period the inorganic phosphorus content of the blood had dropped from an average of 8.15 mg. per

TABLE 11.—*Average Calcium Content of 100 cc. of Blood of the Animals in the Various Groups, by Periods*

Period Ending When Animals Were at Age of	Average Calcium Content per 100 cc. of Blood			
	Group I	Group II	Group III	Group IV
	(mgs.)	*(mgs.)*	*(mgs.)*	*(mgs.)*
8 months	14.86	14.75	14.80	14.54
13 months	14.19	14.72	14.23	14.66
19 months	14.62	13.79	14.16	14.73
25 months	12.54	13.02	13.17	13.44

100 cc. of blood to 4.86 mg. in the case of Group III, and from 7.93 mg. per 100 cc. of blood to 4.35 mg. in the case of Group IV. The phosphorus content of the rations was kept at that level, and the inorganic phosphorus in the blood gradually diminished. This would indicate that the animals must depend upon their feed as the source of the inorganic phosphorus of their blood. These animals had had time to store ample phosphorus in their bones which they could have drawn upon in time of need. This, however, they did not seem able to do, depending entirely upon their food for their supply of phosphorus.

As a general rule the concentration of inorganic phosphorus in the blood of normal-fed animals seemed to increase slightly until the animal was about a year old and then to decrease slightly as the animal grew older.

Study of Individuals. No. E 31, which already has been noted as showing signs of convulsions and bent legs at an early age, showed on her third test the lowest calcium concentration in her blood of any of the animals. Just shortly after this test she developed nervousness, convulsions, and bent legs. On her fourth test the ration had been changed to one containing slightly more calcium and less phosphorus. The concentration of calcium in the blood had increased, but the inorganic phosphorus of the blood then was very low, although the ration had been changed to the low-phosphorus one less than a week previously. This indicates that the concentration of inorganic phosphorus in the blood changes almost as soon as the phosphorus content of the ration is changed.

No. E 28, which developed a sway in her back together with slightly bent legs, was the lowest of all the heifers during the last 3 tests in the inorganic phosphorus content of her blood. The concentration of inorganic phosphorus seemed to be growing less, and at the time of her death it was only 3.14 mg. per 100 cc. of blood.

No. E 29, which was fed the same ration as No. E 28, did not show as marked abnormal characteristics as did No. E 28, and her

blood was not as low in inorganic phosphorus. It, however, was much lower than the blood of the normal animals. Her failure to show marked abnormal characteristics perhaps was due to her individuality, for she was always a strong animal. But she probably would have succumbed later to the effects of the abnormal ration.

The blood of No. E 20, which developed the stiffness in her legs, was low in inorganic phosphorus, but not quite as low as was the blood of No. E 29. It was a little lower than that of her mate, E 21, which did not develop as abnormal characteristics.

This would indicate that the inorganic phosphorus concentration in the blood would be a fairly good index as to whether an animal is receiving sufficient of this element. This apparently is not as true with calcium, although in this particular experiment the amount of calcium in the ration was not reduced to the same extent as it was in the phosphorus rations.

It is difficult to assign a specific value for the normal content of calcium and inorganic phosphorus in the blood of normal animals. Different methods for such determinations have been proposed, many of which do not give concordant results.

Discussion of Results. Meigs, Blatherwick, and Cary *(1919)* found that with calves the plasma calcium tended to become lower

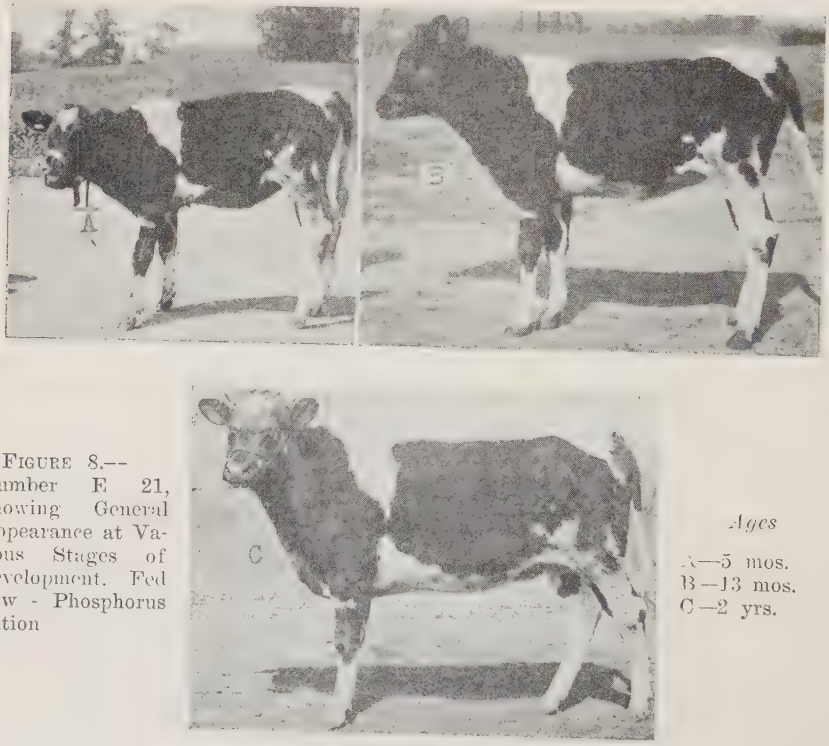


FIGURE 8.—Number E 21, Showing General Appearance at Various Stages of Development. Fed Low - Phosphorus Ration

Ages

A—5 mos.
B—13 mos.
C—2 yrs.

with advancing age up at least to 6 months. The inorganic phosphorus was fairly high at birth but tended to increase until the animal was 6 months of age. Then as a rule it fell off again before the age of 18 months. The calcium in the serum of normal calves they found to be about 10 mgs. per 100 cc., with variations from 9.1 mgs. to 13.7 mgs. The inorganic phosphorus in the serum was found to average 6.5 to 7 mgs. per 100 cc., with variations from 5.6 to 9.2 mgs.

Meigs was able to reduce the inorganic phosphorus in the serum by feeding rations low in phosphorus, but was unable to increase to any extent the calcium in the serum by feeding calcium in the ration. His results indicate that in cattle above two months of age the plasma calcium is little, if at all, altered by pregnancy, lactation, or by feeding rations rich in calcium. This was found also by Halverson and co-workers *(1917)* who found that the calcium content of the serum was little affected by the feeding of calcium in the feed and that it is kept nearly constant by the enormous calcium reserve stored in the bones.

On the other hand, Bethke and co-workers *(1923)* found that in the absence of normal growth in rats there was a general tendency for a reduced calcium content in the blood and ash content of the bones. The phosphorus content of the blood was found more constant, but apparently as the calcium increased there was a tendency for the phosphorus to be depressed.

TABLE 12.—*Average Phosphorus Content of 100 cc. of Blood of Animals in the Various Groups, by Periods*

Period Ending When Animals Were at Age of	Average Phosphorus Content per 100 cc. of Blood			
	Group I	Group II	Group III	Group IV
	(mgs.)	*(mgs.)*	*(mgs.)*	*(mgs.)*
8 months	6.63	7.44	6.79	7.37
13 months	7.08	7.49	8.15*	7.93*
19 months	6.50	7.09	4.93†	4.05†
25 months	5.98	6.31	4.69	3.86

*Only one composite was used, since ration had been changed before the second one was run.

†Three composites were used, since ration had been changed so that they represented the same feeding method.

With the experimental animals it was found that the calcium content of the blood varied from 10.29 to 19.95 mgs. per 100 cc. of the blood. The calcium in the blood was but little affected by the feeding of rations low in this element. This would indicate that the animal body is able to maintain the concentration of the blood fairly uniform when not receiving sufficient in the ration, by drawing upon the supply stored away. It has already been noted that the animals in Groups II and IV were not receiving sufficient calcium as denoted by their growth and development, but the amount in the blood was at all times ample. This agrees with the results of Meigs and co-workers *(1919)* and Halverson and co-workers *(1917)* who found that the concentration of calcium could not be altered greatly by feeding feeds rich in calcium.

It was found, however, that the inorganic phosphorus content of the blood could be easily affected by feeding rations low in phosphorus. This would indicate that the animals depend upon their feed to keep up the supply of inorganic phosphorus in their blood.

If 6 mgs. of inorganic phosphorus per 100 cc. of blood is considered the minimum concentration of phosphorus consistent with the well-being of an animal, then if less than 2 grams of phosphorus per hundredweight of the animal is fed per day, this concentration will not be maintained. It can be seen that the animals in Group 1 were fed a ration slightly below this limit. During the last period they consumed only 1.9 gms. of phosphorus per hundredweight of the animal in their ration, and the concentration of their blood dropped from 6.50 to 5.98 mgs. per 100 cc. This ration contained 0.22 percent phosphorus and was therefore considerably less than the optimal ration of at least 0.4146 percent as recommended by McCollum and associates *(1922)* for rats.

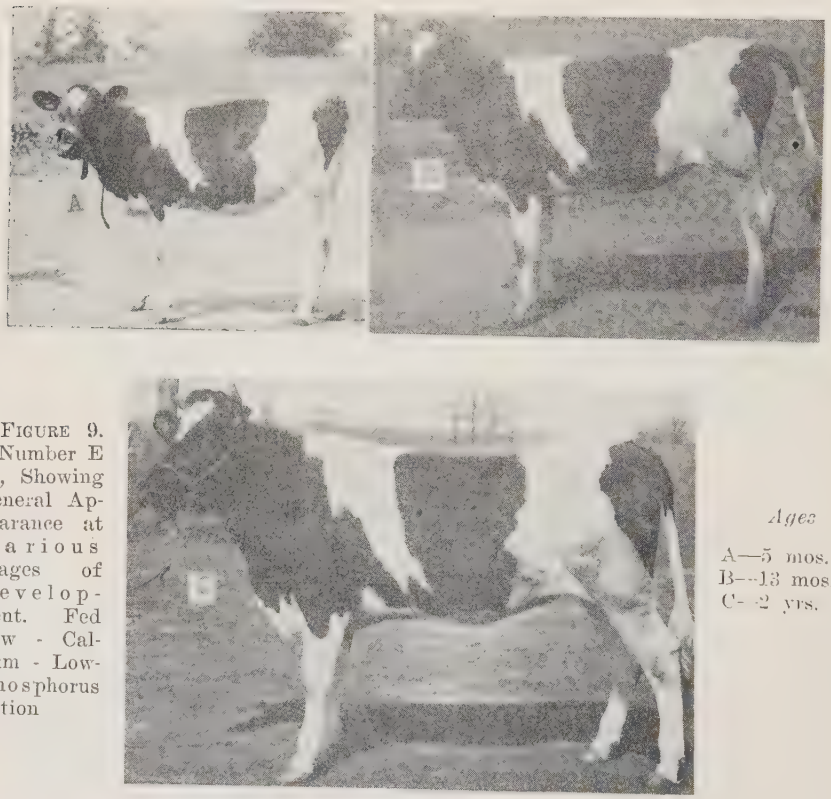


FIGURE 9.—Number E 28, Showing General Appearance at Various Stages of Development. Fed Low-Calcium-Low-Phosphorus Ration

Ages

A—5 mos.
B—13 mos.
C—2 yrs.

Effect of the Rations upon the Bones of the Animals

Effect of Composition. Bones are useful in the animal body first, to act as a support and to give shape to the body; second, to protect some of the vital organs; and third, to act as a storehouse for calcium and phosphorus which might be drawn upon later as the animal finds need for it. It would seem reasonable, therefore, that the bones in animals which have been fed rations low in calcium or phosphorus would be lower in total ash than bones of animals fed normal rations.

Therefore, at the time of killing the animals in the experiment, samples were taken of representative bones of the animals. The bones used were the eleventh and twelfth ribs and the femur and humerus from the left side of each animal. Kruger and Bechdel *(1928)*, studying the normal deposition of minerals in the bones of dairy calves, found that the ribs, femurs, and humeri were very suitable for such studies, more so than some other bones which they also studied.

Sampling the Bones. The bones were removed from the carcass very soon after slaughter, scraped free of all adhering flesh, and carefully weighed.

The ribs were sampled by taking pieces about two inches in length from near both ends and from the middle of each. These were carefully weighed and placed in a mason jar which had previously been weighed. They were kept sealed and in a cold room at a temperature of about zero until the time of analysis. The two ribs were then analyzed together.

The femurs and humeri were sampled the first two times by taking a piece 2½ inches in length from the middle of the shaft of each bone. Upon realizing that this was not a fair sample of the entire bone, this method was changed and during the last two times a longitudinal medial section about 3/16 inch thick was sawed out of each bone.* These were weighed, sealed in a mason jar, and kept in a cold room as were the ribs until the time of analysis. The femurs and humeri were analyzed together. All samples of bones were kept in this manner and analyzed at the same time.

Method of Analysis. At the time of analysis the jars containing the bones were weighed carefully and air-dried at room temperature. The bones were then broken up in an iron mortar and the remaining moisture was determined by drying for 48 hours in a vacuum oven maintained at 75°C. and at a reduced pressure of 27.5 inches of mercury. The dry broken bones were extracted with ether for 24 hours in a large soxhlet, dried, and ground to pass a 20-mesh sieve. Five grams of the ground bone was extracted for 24 hours with ether and then for 36 hours with 95 percent alcohol. The dry-extracted bone was transferred to a platinum dish and ashed in an electric muffle at a low red heat. The ash was dissolved in 4-molar hydrochloric acid.

*Suggested by Minnesota Agricultural Experiment Station.

The phosphorus was determined by the official method and the calcium by a slight modification of the McCrudden method. The non-extractable organic matter of the green bone was determined by subtracting the sum of the moisture, extractable material, and ash from 100. It seemed that a better picture of the bone could be obtained if the extractable material, which consists largely of fat and fat-like materials, is not combined with the non-extractable organic materials, as these are usually under the name of organic matter.

Analysis of Ribs. Table 13 gives the average percentage of the various constituents in the green bone by periods. This is also expressed in percentages of the normal-fed group.

It will be noted in a study of Table 13 that in general the percentage of the ash and the non-extractable organic matter is decreased, and the percentage of water and extractable material is increased in the bones of animals fed rations low in calcium or phosphorus as compared to the bones of normal-fed animals. The percentage of calcium and phosporus in the bones, of course, was decreased as the ash decreased.

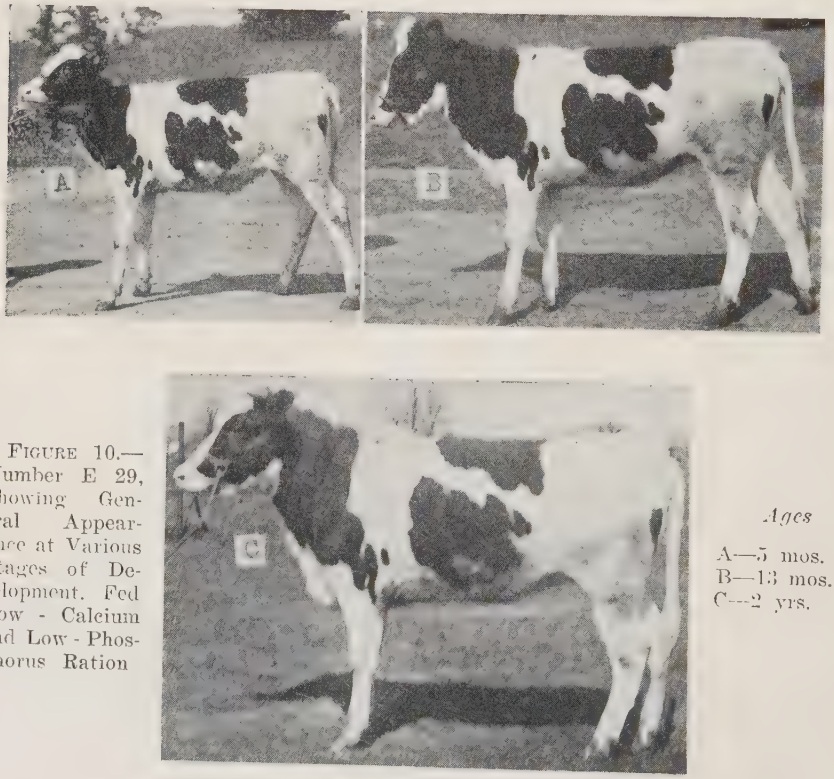


FIGURE 10.—Number E 29, Showing General Appearance at Various Stages of Development. Fed Low - Calcium and Low - Phosphorus Ration

Ages

A—5 mos.
B—13 mos.
C—2 yrs.

TABLE 13.—*Average Percentage of Various Constituents in Green Bone (Ribs) of the Various Groups, by Periods; Expressed also as Percentage of the Normal Group*

Period Ending When Animals Were at Age of	Average Percent in Ribs of Group I (Normal)	Average Percent in Ribs of Group II	Percent of Normal Group	Average Percent in Ribs of Group III	Percent of Normal Group	Average Percent in Ribs of Group IV	Percent of Normal Group
			MOISTURE				
8 mos.	15.22	16.27	106.9	14.90	97.9	14.71	96.7
13 mos.	18.45	19.57	106.1	22.70	123.0	19.90	91.6
19 mos.	17.33	15.10	87.7	18.41	106.2	18.55	107.0
25 mos.	15.08	15.52	102.9	17.68	117.2	20.93	138.7
			EXTRACTABLE MATERIAL				
8 mos.	7.74	15.80	204.1	5.95	75.5	11.73	151.1
13 mos.	9.81	8.97	91.4	10.89	111.0	11.12	113.3
19 mos.	14.21	21.11	149.2	15.32	107.7	25.16	177.7
25 mos.	13.33	14.61	109.6	18.15	136.1	19.99	150.0
			NON-EXTRACTABLE ORGANIC MATTER				
8 mos.	30.96	27.60	89.1	31.28	101.1	29.94	96.7
13 mos.	27.87	29.37	105.4	26.12	96.8	29.82	107.0
19 mos.	26.13	25.15	96.2	26.21	100.3	23.14	88.5
25 mos.	27.31	26.71	97.7	25.23	92.4	26.07	95.4
			ASH				
8 mos.	46.08	40.31	87.5	47.96	104.1	43.56	94.5
13 mos.	43.87	42.08	95.9	40.29	91.8	41.65	94.5
19 mos.	42.36	38.63	91.2	40.04	94.5	33.14	78.2
25 mos.	44.27	43.15	97.4	38.93	87.9	33.01	74.5
			CALCIUM				
8 mos.	18.25	15.87	86.9	19.07	104.5	17.20	94.2
13 mos.	17.51	16.74	95.6	16.16	92.3	16.59	94.7
19 mos.	16.72	15.37	91.9	16.26	97.2	13.57	81.2
25 mos.	17.68	17.20	97.3	15.68	88.7	13.42	75.8
			PHOSPHORUS				
8 mos.	8.75	7.70	88.0	9.08	103.8	8.26	94.4
13 mos.	8.25	7.97	86.9	7.60	92.1	7.90	96.1
19 mos.	7.96	7.28	91.6	7.42	93.2	6.25	78.5
25 mos.	8.21	8.05	98.0	7.23	88.1	6.09	74.2

Extractable material and water seem to replace the ash and to a certain extent the non-extractable organic matter in the bones as the animal is deprived of normal rations. In the case of the animals in Group IV, which were fed a ration low in both calcium and phosphorus, at the end of the experiment the amount of ash and of calcium and phosphorus in the ribs was only about three-fourths of the amount in the bones of the normal-fed animals.

In Table 14 the average ash of the dry-extracted ribs and also the average percentage of calcium and phosphorus in the ash are given by periods and groups.

Table 14 shows that as the ration is limited in calcium and phosphorus, the amount of ash in the dry-extracted bone also is lowered in a very similar way as it is with the green bone, but since the water and extractable material had been removed the results were not as pronounced. The amount of calcium and phosphorus in the ash is affected but little by the ration fed.

Analysis of Femur and Humerus. Table 15 shows the average analysis of the various constituents of the bones for the different groups by periods.

The same general results were obtained by these analyses as by analyses of the ribs. Very little effect was shown at first when the ration was not reduced, but as soon as the rations were reduced there was an immediate effect upon the composition of the bones. This, in general, was a reduction in the ash and non-extractable organic matter and an increase in water and extractable material. The calcium and phosphorus also were reduced as the ash was reduced. The bones of the low-mineral-fed groups were affected, but the effects were more pronounced as to their calcium and phosphorus content.

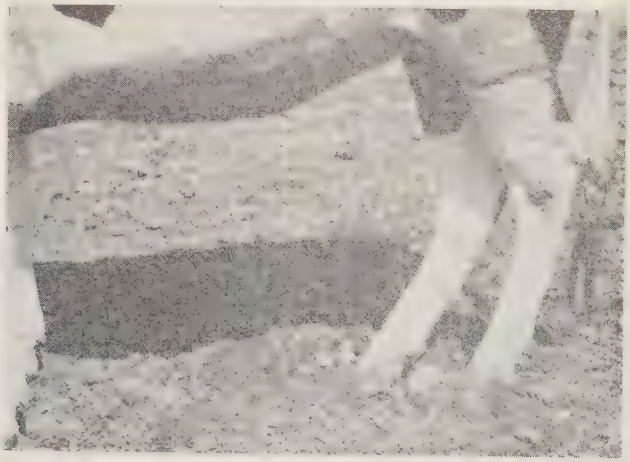


FIGURE 11.—Showing the Legs of E 20. Note That They Are Slightly Bent. Taken at Time of Killing

There was an indication that the shaft of the bone is more stable in its composition than the ends of the bone. The bones of the low-mineral-fed groups during the first two periods when the samples were taken from the center of the bone were as high and in most cases higher in ash content and in their content of calcium and phosphorus than were the bones of the normal-fed group, while the ribs during the corresponding period showed some effect of the decreased mineral supply. When, however, the sampling was changed to include the entire length of the bone, the effect was just as pronounced with the femurs and humeri as with the ribs. This is as might be expected, however, since the growing parts of the bones are at the ends and these naturally would be the first affected.

The average amount of ash in the dry-extracted femur and humerus and the amount of calcium and phosphorus in the ash of the individual animals, averaged for groups by periods, is given in Table 16.

Table 16 shows again that in the dry-extracted bones the amount

TABLE 14.—*Average Percentage of Ash in Dry-Extracted Ribs, and Average Percentage of Calcium and Phosphorus in Ash of Ribs, Given as the Average of All Groups by Periods; Expressed also as Percentage of the Normal Group*

Period Ending When Animals Were at Age of	Average Percent in Dry-Extracted Ribs of Group I (Normal)	Average Percent in Dry-Extracted Ribs of Group II	Percent of Normal Group	Average Percent in Dry-Extracted Ribs of Group III	Percent of Normal Group	Average Percent in Dry-Extracted Ribs of Group IV	Percent of Normal Group
ASH (DRY-EXTRACTED)							
8 mos.	59.86	59.35	99.1	59.80	99.9	59.16	98.8
13 mos.	61.15	58.88	96.2	59.92	98.0	57.93	94.7
19 mos.	61.36	60.57	98.7	60.44	98.5	58.83	95.8
25 mos.	61.89	61.70	99.3	60.67	98.0	55.74	90.0
CALCIUM IN THE ASH							
8 mos.	39.61	39.26	99.3	39.77	100.4	39.48	99.4
13 mos.	39.91	39.79	99.7	40.12	100.5	39.83	99.8
19 mos.	40.03	39.80	99.4	40.60	101.4	40.96	102.3
25 mos.	39.93	39.87	99.8	40.28	100.8	40.64	101.8
PHOSPHORUS IN THE ASH							
8 mos.	18.98	19.09	100.5	18.97	100.0	18.96	99.9
13 mos.	18.91	18.94	100.1	18.88	99.8	18.97	100.3
19 mos.	18.80	18.87	100.3	18.53	98.5	18.56	98.7
25 mos.	18.56	18.61	100.3	18.55	100.0	18.45	99.4

of ash is lessened by feeding rations restricted in calcium or phosphorus. The same general results were obtained as with the green bones but the differences were not as pronounced. The composition of the ash is affected but little in regard to its calcium and phosphorus content.

Discussion of Results. The results of the analyses of the ribs and of the femur and humerus of the various animals in a general way are similar, except for the different methods of sampling used during the first two periods with the femur and humerus. As a rule, when the analyses of the ribs varied from normal, the analyses of the femur and humerus of the same group would vary in like manner. This would indicate that either type of bone could be used equally well in studying the effects of rations low in calcium or phosphorus upon the bones of animals. Both indicated that rations low in one or both minerals, but normal in regard to digestible protein and digestible nutrients, when fed to growing dairy animals, bring about a change in the composition of the bones of such animals. Such a change is characterized by an increase in the water and extractable material in the bone and by a corresponding decrease of the ash and non-extractable organic matter. The amount of calcium and phosphorus of the green bone also was decreased. The dry-extracted bone also shows less ash when such rations are fed, but not to the same extent as in the green bone. As far as the ash was concerned it contained practically the same percentage of calcium and phosphorus as did the bones of calves on normal rations.

It will be noted that the bones of the animals in the normal-fed group maintained fairly uniform composition at the different ages

TABLE 15.—*Average Percentage of Various Constituents of Green Bone (Femur and Humerus) in the Various Groups, by Periods; Expressed also as Percentage of the Normal Group* *

Period Ending When Animals Were at Age of	Average Percent in Femur and Humerus of Group I (Normal)	Average Percent in Femur and Humerus of Group II	Percent of Normal Group	Average Percent in Femur and Humerus of Group III	Percent of Normal Group	Average Percent in Femur and Humerus of Group IV	Percent of Normal Group
			MOISTURE				
8 mos.	11.65	9.32	80.0	10.76	92.4	11.50	98.7
13 mos.	13.50	13.26	98.2	14.14	95.3	14.66	108.6
19 mos.	17.35	17.92	103.3	16.45	105.2	17.68	101.9
25 mos.	13.64	15.55	113.6	15.94	116.9	19.90	145.9
			EXTRACTABLE MATERIAL				
8 mos.	3.27	4.77	145.9	4.88	149.2	1.50	45.8
13 mos.	1.81	0.60	33.1	0.51	28.2	0.89	49.2
19 mos.	28.73	29.40	102.3	29.49	102.6	36.69	127.7
25 mos.	31.60	30.68	97.7	34.16	108.1	39.40	124.3
			NON-EXTRACTABLE ORGANIC MATTER				
8 mos.	26.72	25.57	95.6	25.35	94.4	26.30	98.4
13 mos.	27.91	27.08	97.0	27.19	97.4	26.65	95.5
19 mos.	19.21	20.10	104.7	19.39	100.9	16.47	85.7
25 mos.	19.04	20.19	102.8	18.29	92.6	17.94	86.3
			ASH				
8 mos.	58.34	60.33	103.4	58.91	100.9	60.70	102.3
13 mos.	58.27	60.06	103.1	58.61	100.6	57.84	99.2
19 mos.	34.70	32.58	93.8	34.66	99.8	29.12	83.9
25 mos.	35.06	33.08	94.3	31.60	90.1	22.75	64.8
			CALCIUM				
8 mos.	23.13	23.88	103.2	23.40	101.1	24.03	103.8
13 mos.	23.03	23.84	103.5	23.40	101.1	23.06	100.1
19 mos.	13.83	19.97	93.8	13.85	100.1	11.81	85.4
25 mos.	13.89	13.13	94.5	12.04	91.0	9.14	65.8
			PHOSPHORUS				
8 mos.	10.89	11.23	103.1	10.10	92.7	11.30	103.7
13 mos.	10.91	10.79	98.9	11.00	100.8	10.91	100.0
19 mos.	6.45	6.15	95.3	6.44	99.9	5.39	82.9
25 mos.	6.61	6.41	96.9	5.94	89.8	4.28	64.7

during the entire experiment. There were slight variations from one period to another but the differences were not great.

The bones of the animals in Group II, which was fed a ration low in calcium throughout the experiment, showed the typical variation in composition. In general, from the first they were high in moisture and in extractable material and low in non-extractable organic matter and in ash. The ash seemed to increase toward the latter part of the experiment. This checks with observation, since the animals in this group seemed to improve in general appearance and thrift toward the end of the experiment. They, however, were fed the same ration at all times. The only explanation for this is that the requirements for calcium were lowered as the animals approached maturity and were not growing so fast as previously, and that, while the ration was not sufficient when the animals were younger and growing fast, it was sufficient when this period of rapid growth was

*It must be borne in mind in studying Table 15 that the first two analyses given in the table cannot be compared directly with the last two analyses, since different methods of sampling were used. The first two and the last two can be compared, and in a general way all four can be considered together.

over. At any rate, the bones of the animals in this group from the analyses seemed to be approaching normal toward the end of the experiment.

The bones of the animals in Group III, the low-phosphorus group, after the first period, when their ration approximated normal, showed the same general composition as the low-calcium group. The ash and non-extractable organic matter was found decreased while the water and extractable material was increased. Here, again, the composition of the bones correlated with the general appearance of the animals. Individuals in this group, as was seen, had developed abnormal characteristics during the last period, and the analyses show that the bones of this group at the last killing contained over 10 percent less ash than those of normal-fed animals.

FIGURE 12.—Showing E 28. Note the Sway in Her Back. Taken at Time of Killing

The bones of the animals in Group IV showed the greatest difference in their composition. This group was fed a ration low in both phosphorus and calcium. The ration, however, was not low in phosphorus until almost the time of the second killing; consequently during the first two periods the bones should compare with those in Group II. The analyses show a fair degree of comparison between the two groups. During the last two periods the ration of Group IV was very low in phosphorus and consequently its bones were much reduced in ash. The ribs contained scarcely 75 percent and the femur and humerus scarcely 65 percent as much ash as the normal bone at the time of the final killing. The animals in this group at that time were growing slowly and had developed abnormal characteristics, shown by the sway in the back of individual animals. The bones of these animals contained more moisture and were very much higher in the amount of extractable material than the bones of normal-fed animals.

The results found in this study were very similar to those obtained by other investigators, since many have found that the ash content

TABLE 16.—*Average Percentage of Ash in Dry-Extracted Femurs and Humeri, and Average Percentage of Calcium and Phosphorus in Ash, Given as the Average of All Groups, by Periods; Expressed also as Percentage of the Normal Group*

Period Ending When Animals Were at Age of	Average Percent in Dry-Extracted Femur and Humerus of Group I (Normal)	Average Percent in Dry-Extracted Femur and Humerus of Group II	Percent of Normal Group	Average Percent in Dry-Extracted Femur and Humerus of Group III	Percent of Normal Group	Average Percent in Dry-Extracted Femur and Humerus of Group IV	Percent of Normal Group
			ASH				
8 mos.	69.24	70.25	101.4	70.13	101.3	69.76	100.7
13 mos.	68.79	69.72	101.3	68.67	99.8	69.49	101.0
19 mos.	64.36	61.85	96.2	64.13	99.6	61.75	95.9
25 mos.	64.08	62.95	98.2	63.15	98.5	57.09	89.1
			CALCIUM				
8 mos.	39.65	39.58	99.8	39.72	100.2	39.58	99.8
13 mos.	39.53	39.70	100.4	39.92	100.9	39.87	100.8
19 mos.	39.86	39.82	99.9	39.96	100.2	40.54	101.7
25 mos.	39.63	39.68	100.1	39.99	100.8	40.19	101.4
			PHOSPHORUS				
8 mos.	18.62	18.61	100.0	17.12	91.9	18.63	100.0
13 mos.	18.73	18.79	100.3	18.76	100.1	18.87	100.7
19 mos.	18.75	18.88	100.7	18.57	99.0	18.50	98.6
25 mos.	18.85	19.10	101.3	18.81	99.8	18.84	100.0

of bones is lowered when animals are fed rations low in minerals. Voit *(1880)* found that the skeleton of pigeons and of puppies became weakened and porous on rations low in calcium. He described the condition as rachitic. Weiske and Wildt *(1873)* found that with lambs fed rations low in calcium and phosphorus, the ratio of the two minerals in the compact part of the bone remained the same as in the normal bone but that the percentage of calcium and phosphorus was reduced.

Maynard, Goldberg, and Miller *(1925)* found that the bones of stiff pigs, fed a calcium-deficient diet, were markedly lower in dry matter, ash, calcium, and phosphorus than litter mates which received adequate rations. Increasing the amount of calcium in the basal ration by adding bonemeal or limestone produced bones much higher in calcium and phosphorus and saved the animal from stiffness. There was a striking tendency for the calcium and phosphorus ratio to remain constant in the bone ash.

Hart, McCollum, and Fuller *(1909)* found that on rations extremely low in phosphorus the percentage of ash in the skeleton of pigs was reduced to nearly one-half that of pigs receiving normal rations. They also found that the calcium and phosphorus tended to remain in the same proportion as in the normal pig. This indicates that when an animal is starved for phosphorus it draws this element from the skeleton but removes calcium and phosphorus in the proportion found in tri-calcium phosphate.

In studies of bone growth Hammett *(1925, 1925a, 1925b)* found that the humerus and femur decreased in water content and increased in ash content as the animal grew older. The organic matter con-

tinued about the same. The calcium in the bones increased as the animal grew older and the phosphorus and magnesium percentage decreased. The change in the composition was practically complete at 75 days of age, the end of puberal period.

Kruger and Bechdel *(1928)* experimenting with dairy calves under 6 months of age found that the percentage of phosphorus and calcium in the bone ash is nearly constant and varies only slightly with the age of the animal. The percentage of water decreases, while the percentage of ash and organic matter increases with the age of the animals. The ash replaces the greater part of the decrease in the water percentage.

Effect on Appearance. Figures 13 and 14 show the appearance of the femurs of animals from each group at the time of the last killing.

The appearance of the femurs and humeri of the different groups at that time were quite noticeably different.

The femurs and humeri of the animals in the normal group were dense at the end and hard in the shaft. The walls of the shaft were thick and the amount of marrow was only 8.2 percent of the weight of the bone. The entire bone was well calcified.

FIGURE 13.—Cross-section of Femur of Animals E 5, from the Normal Group, and E 20, from the Low-Phosphorus Group

The femurs and humeri of the animals in Group IV, the low-calcium-low-phosphorus group, were spongy and soft at the ends. The shaft while hard was not as thick as the normal bone, and there was a larger amount of marrow. Upon weighing it was found that 10.3 percent of the weight of the bone was marrow. The ends of the bones were not well calcified but took of the nature of a rachitic

bone as described by McCollum and Simmonds *(1927)*. They state that "in the rachitic bone all the processes of growth and the maintenance of equilibrium are abnormal. Calcium salts are not deposited in the normal way. In a normal bone the junction of the cartilage with the shaft forms a straight regular line. In the rachitic bone it is ragged because there is no provisional zone of calcification and the cartilage is invaded by large tufts of blood vessels from the shaft which destroy it irregularly. At the same time masses of cartilage persist where they should be destroyed, and islands remain cut off from the main body of the tissue. Osteoid is not calcified, as it is formed either in the trabeculae or by the periosteum, so that the bone becomes soft. The animal attempts unsuccessfully to compensate for the weakness due to the lack of lime salts by producing osteoid tissue in abnormal amounts, especially at points subject to stress and strain. . . . This overproduction of osteoid and cartilage causes irregular enlargements of the bones, and their weakness consequent upon the lack of lime salts results in bowing and fracture."

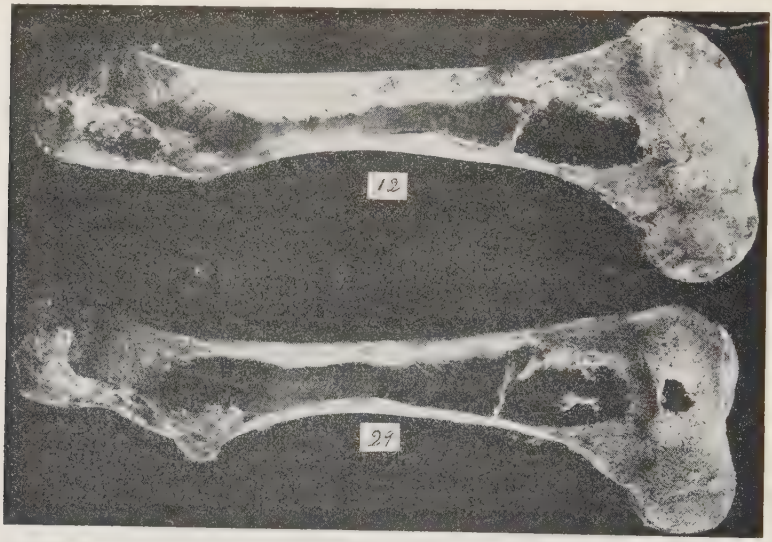


FIGURE 14.—Cross-section of Femur of Animals E 12, from the Low-calcium Group, and E 29, from the Low-calcium-low-phosphorus Group

When these bones were allowed to remain for a few days in a room of ordinary temperature, they became dark in color and expelled a considerable amount of moisture. After allowing the tarsal bones to remain for several days in this manner, it was found that the shaft had split longitudinally at two or three places and had expelled a large amount of moisture.

The femurs and humeri of the bones in Group II, the low-calcium group, were very similar to those of Group IV. They were soft and spongy at the ends but in this respect were not so bad as were those

of Group IV. The shaft was dense but the walls were thin. It was found that 10.4 percent of the weight of the bone was marrow. The bones upon standing showed the same general characteristics as those of Group IV.

TABLE 17.—*Average Breaking Strength of Tarsal Bone of Animals in the Various Groups*

Item	Group I		Group II		Group III		Group IV	
	19 mo.	25 mo.	19 mo.	25 mo.	19 mo.	25 mo.	19 mo.	25 mo.
Average weight of animals *(pounds)*	764	966	688	833	721	924	645	782
Breaking strength of bones *(pounds)*	1135	2020	942	1490	1165	2030	915	1010
Breaking strength of bones per cwt. of animal *(pounds)*	148.5	209.1	136.9	178.9	161.6	218.5	141.8	129.1
Average breaking strength *(pounds)*	1572		1261		1597		962	
Average breaking strength per cwt. of animal *(pounds)*	178.8		157.9		190.0		135.4	
Percent of normal group..	100.0		89.4		106.2		75.7	

The femurs and humeri of the animals in Group III, those fed the low-phosphorus ration, were somewhat different from the ones already described. While the ends of the bones were soft and spongy and not well calcified, the center of the bone was hard and the walls were as thick as those of the animals in the normal group. The amount of marrow also was about the same as in the normal bones, as 8.3 percent of the bone was marrow. These bones seemed to be affected more at the ends than in the shaft.

At time of slaughter it was found that there was a slight enlargement at the costochondral junction of the ribs of the animals in Groups II and IV. These could not be described as "beads," but at the point of junction there were enlargements surrounding the junction which seemed to consist largely of fat or fat-like material. This is shown in Figure 15 for the animal E 28. The ribs of these two Groups, especially the twelfth, were not well calcified and upon standing turned dark and emitted moisture. In the case of the animals in group IV it was found that the twelfth rib was composed largely of cartilage. This was not shown as pronounced in the animals of the other groups.

Effect of Breaking Strength. The breaking strength was determined of the tarsal bone taken from the left leg of the animals at the ages of 19 months and 25 months. These were all determined at the same time after the first set of bones had dried out for some time. The two therefore are not strictly comparable.

Since the animals were not all of the same size the breaking strength of the bones was calculated per hundredweight of the animal. The results are given in Table 17.

It will be noted that whereas the breaking point of the bones of Groups II and IV was below that of the normal-fed group, that of Group III was above.

The breaking strength of the bones was taken on the shaft. The bones of the animals in Group III, as shown by a study of their composition, were affected just as much or even slightly more than were those of the animals in Group II, but only ends of the bones were affected. The shaft of the bones was just as thick as shown by measurements, by breaking strength, and by the amount of marrow, as was the shaft of the bones of the animals fed normal rations. This would seem to substantiate the indication already mentioned that, while the animal has the power to draw upon the storage of calcium in the bone in order to maintain the normal amount in the blood, it does not have the power to draw upon the reserve of phosphorus sufficiently to keep the inorganic phosphorus of the blood normal.

The breaking strength of the bones of the animals in Group II, the low-calcium group, was only 89.4 percent, and that in Group IV, the low-calcium-low-phosphorus group, was only 75.7 percent of the breaking strength in the normal-fed group.

Summary. Feeding rations to growing dairy animals which are low in calcium or phosphorus or in both these minerals results in changes in the bones as shown by analysis, breaking strength, and appearance.

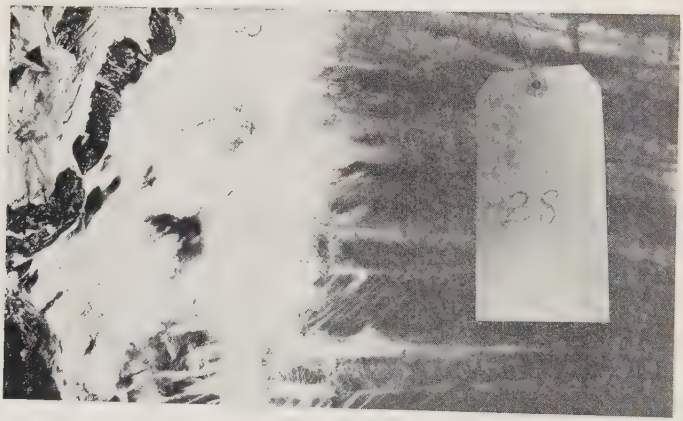


FIGURE 15.—Showing Enlargements Surrounding Junctions of Ribs in Animal E 28

In general the analyses of such bones show that the ash and non-extractable organic matter are reduced while the moisture and extractable material are increased. The ash of the bones of the animals of Group IV, the group fed the ration low in both calcium and phosphorus, was more than 25 percent lower than that of the group fed the normal ration, while the ash of the animals in Groups II and III was lower than that of the normally-fed animals.

The bones of the low-mineral-fed animals were not calcified as well as those of the normal-fed group, and the breaking strength, with the exception of Group III, was considerably less than that of the animals fed the normal ration.

TABLE 18.—*Average Weight of Internal Organs on Basis of Hundredweight of Animals, and Average Dressing Percentage of Each Group, by Periods*

Period Ending When Animals Were at Age of	Group I	Group II	Group III	Group IV
		HEART		
	(gms.)	*(gms.)*	*(gms.)*	*(gms.)*
8 mos.	189	179	164	185
13 mos.	163	162	158	199
19 mos.	148	154	151	171
25 mos.	153	148	150	189
		LIVER		
8 mos.	610	548	560	531
13 mos.	484	564	490	624
19 mos.	441	446	472	468
25 mos.	393	416	394	403
		BRAIN		
8 mos.	70	67	63	73
13 mos.	70	69	62	75
19 mos.	42	52	44	54
25 mos.	38	47	37	43
		SPLEEN		
8 mos.	72	72	63	76
13 mos.	79	92	63	82
19 mos.	69	58	63	81
25 mos.	64	65	71	89
		DRESSING PERCENTAGE		
8 mos.	47.5	43.5	44.7	44.2
13 mos.	49.2	48.5	50.8	49.0
19 mos.	52.9	51.6	56.0	50.1
25 mos.	59.1	50.7	58.5	55.8

The results would indicate that a study of the bones of growing dairy animals is a very good index as to whether the animals are receiving sufficient minerals, and, furthermore, that any of the long bones can be used with equal success for such study.

Effect of Rations upon Internal Organs and Dressing Percentage

At the time of slaughtering the animals an examination was made of their internal organs. These were removed, examined, and carefully weighed. Since the weight of the animals varied considerably in each group, the weights of the different organs were converted to the live weight basis of the animals. In Table 18 the average weights of the heart, liver, spleen, and brain of the groups are given for the various periods on the basis of a hundredweight of the animals. This table also gives the dressing percentage of each group by periods.

Table 18 shows that as the normal-fed animals grow older the weight of their internal organs increases, but not in proportion to their live weight. When it is expressed on the basis of a hundredweight of the animal, the weight of the heart, liver, brain, and spleen all decrease as they grow older. In general this also seems to be the case with the animals in the other groups. The spleen, however, of the animals in Groups III and IV seems to increase at a faster rate than the live weight of the animals as they grow older. This was especially noticeable in the case of the animals in Group IV. The animals in this group on the hundredweight basis seemed to increase in the size of all the organs in comparison with the animals in the

normal-fed group. This was true but less pronounced of the animals in Group II and was least shown by those in Group III.

The animals in Groups I and III averaged highest in dressing percentage, which increased as the animals grew older. It was also observed that the animals in these two groups were in better condition as to flesh than those in Groups II and IV. This would indicate that the difference in the size of the internal organs might be due largely to the difference in the mineral content of the ration.

No difference was noted in the general appearance of the organs of the several groups.

GENERAL DISCUSSION OF RESULTS

In bringing together the results of the experiment it is evident that the animals in Group I, the group which was fed a ration typical of those fed under practical conditions, obtained sufficient calcium and phosphorus for normal growth and development. They did not grow as well as might have been expected during the first year, but this probably was due to the poor start which they received and not to any deficiency in their ration. At the time of the last analyses the inorganic phosphorus in their blood was slightly low. This may have been due to the low phosphorus content of the ration, which during the last periods contained only 0.22 percent phosphorus and was providing only 1.9 gms. of phosphorus per day per hundredweight of the animal.

The optimum requirement for laboratory animals as found by McCollum and coworkers *(1922)* was 0.4146 percent phosphorus. This ration contained only a little more than one-half of this amount; in fact none of the rations fed after milk-feeding was discontinued contained as much phosphorus as this amount. It would hardly be expected, since the dairy animal is not as fast a growing animal as the rat, that it would require as much phosphorus in the ration as does the rat.

Armsby *(1917)* calculated that during the first year the normal animal retains 1.7 gms. of phosphorus daily per hundredweight of the animal. Since the animals in the normal group were receiving only a little more than is retained by normal animals, it can be seen that the animals in this group were being fed a ration dangerously close to the lower limits of phosphorus requirements.

Since this ration was being used as one typical of those being fed under practical conditions, the danger of underfeeding of phosphorus is evident. The animals in this group, however, were normal in weight and height at withers after the first year, were in good physical condition, and showed no abnormal physical characteristics throughout the experiment. Hence they must have received sufficient calcium and phosphorus.

The animals in Group II were fed a ration low in calcium but containing a little more phosphorus than was contained in the ration fed to the animals in the normal group. Any abnormal condition in

the animals of this group can be attributed to the low calcium content of the ration, since all animals were fed according to their requirements for digestible protein and digestible nutrients.

The ration fed during the first year contained 0.286 percent calcium and during the second year 0.249 percent. This during the first year was about 3.5 gms. and during the second year about 2.75 gms. per hundredweight of the animal. McCollum and coworkers *(1922)* found that the optimum requirement of calcium for growing rats was 0.641 percent, and Armsby *(1917)* calculated that the amount retained by normal cattle during the first year was 3.2 gms. of calcium per day per hundredweight of the animal. The ration fed contained in proportion considerably less than one-half of the optimum requirements for rats and during the first year just a little more than is retained by normally growing cattle. During the second year the ration contained a little less than is retained by normally growing cattle. It is evident then that these rations were low in their calcium content. The rations contained a little more phosphorus than did those fed to Group I and therefore they should not be lacking in phosphorus.

The animals in Group II did not grow so well, especially during the second year, as did those in Group I. This was shown both by weight and by height at withers. Neither were they in as good physical condition at any time, as shown by general appearance and dressing percentage. The blood, however, remained normal in its calcium and inorganic phosphorus content. Analyses showed that the green bones of the animals in this group were lower in ash and consequently lower in both calcium and phosphorus than were the bones of the normal group. The bones were slightly higher also in moisture and extractable material. This condition was true during the entire experiment, but it seemed to be improving toward the end of the trial. The circumstance would indicate that the animals as they grew older did not require as much calcium as they did when they were younger and making faster gains.

These animals averaged about 1½ months older at the time of the first signs of oestrum than those in Group I, and they were quite irregular thereafter. However, other than being in not quite as good condition and not growing quite as fast as Group I, Group II showed no abnormal physical characteristics. Their bones indicated, however, that they were being fed a ration too low in calcium for best development, but since they were kept for so long a time without very striking results, it would indicate that the ration was only slightly low in this element.

The animals in Group III during the second year were fed a ration containing only 0.131 percent of phosphorus. This provided about 1.43 gms. of phosphorus per day per hundredweight of the animals. The amount of calcium in the ration was about the same as in the ration fed to the animals in the normal group. Any abnormal condition in the animals of this group can be attributed to the lack of phosphorus in the ration. It must be borne in mind, however, that

the ration fed to the animals in this group was normal in its amount of phosphorus during most of the first two periods. Hence the effects of the ration fed could not be expected before this time, as it was then equal in both calcium and phosphorus to the ration fed to the normal group. Therefore only the difference noted during the latter part of the experiment is significant.

The animals in Group III grew almost as well as did those in Group I, both in height at withers and in weight during the first year, but during the last year they did not make quite as good gains. Their growth curves show them to have made much better gains than those in either Groups II or IV but this may have been due largely to the better start which they obtained because of the normal ration which they received during the first year. They were in better condition than those in Groups II and IV, as shown by dressing percentage and general appearance, but this again may have been due to the better start which they received. The first period of oestrum occurred at about the same time as that of the normal group, but that also would be as expected, since they were receiving a normal ration up to about that time.

When their ration was changed to a low-phosphorus ration, however, within a week the inorganic phosphorus in the blood had dropped to almost one-half what it had been previously and it remained there throughout the rest of the experiment.

Toward the end of the experiment one of the animals in this group became stiff in the hind legs, and the legs became slightly bent. The other animal became slightly sway-backed.

The amount of ash in the green bone also fell and continued low until the end of the experiment. This as usual was accompanied by a rise in the moisture and extractable material of the bones. The breaking strength of the bones remained normal in this group and the amount of marrow in the bones also was normal.

A study of these results indicates that the growing dairy animal must depend for her phosphorus supply largely upon her feed, especially when she is obtaining sufficient calcium in her feed. This is indicated first because of the almost immediate decrease in the inorganic phosphorus of the blood when rations below the needs of the animal were fed; and second, whereas the total ash in the bones was decreased below normal, the shaft of the bone was not decreased in strength and there was no more marrow in it than in the normal bone.

While the ash content of the bones in the animals fed the low-calcium ration was no less than it was in Group III, nevertheless the breaking strength of the bones was reduced, and the marrow increased in amount, notwithstanding the fact that the calcium content of the blood was not decreased. This would seem to indicate that, whereas the animal may draw upon the bone for its calcium in order to keep its blood supply normal, it cannot do so for phosphorus, especially if there is sufficient calcium in the ration. If this is true it might explain one of the reasons why the ratio of these elements should be kept within certain limits.

The results also indicate that it is much easier to affect the phosphorus supply of the blood than the calcium supply in growing dairy animals. This is shown in a comparison of Groups II and III. The bones of both of these groups were affected in comparison to about the same degree, but whereas the blood of Group IV was lowered materially in phosphorus, that of Group III was maintained at normal in calcium.

Group IV was fed a ration low in calcium and after the first two periods low also in phosphorus. During the first two periods the ration compared with that fed to Group II, and the results were very similar. They grew at about the same rate as indicated by weight and height at withers. The results of the analyses of the bones also were very similar.

At about the end of the second period the ration fed was low also in phosphorus, containing only about 0.133 percent of that mineral. The inorganic phosphorus content of the blood immediately dropped to about one-half that of normal. The calcium content of the blood remained normal throughout the entire experiment, however. This group showed more serious symptoms than any of the others. The composition of the bones was greatly affected. The ash was lowered to less than three-fourths that of normal bones and contained much more moisture and extractable material than normal bones. The calcium and phosphorus were correspondingly lowered. The breaking strength of the bones was not much over one-half that of normal bones. The animals also took on abnormal appearance toward the end of the experiment. They became sway-backed and one individual became slightly bent in the legs.

This ration was very similar to Ration II in its calcium content (slightly higher) and to Ration III in its phosphorus content (slightly higher), but the effects were much worse than in either of these groups. This would show that both calcium and phosphorus were too low in these rations for the normal well-being of the animals.

SUMMARY AND CONCLUSIONS

Four groups of growing dairy animals were fed in such a way that all were receiving approximately the same amount of digestible crude protein and total digestible nutrients. Group I was fed a supposedly normal ration in so far as its content of phosphorus and calcium was concerned. Group II was fed a ration low in calcium but with sufficient phosphorus. Group III was fed a ration low in phosphorus but with sufficient calcium, and Group IV was fed a ration low in both calcium and phosphorus. No effort was made to supply the anti-rachitic vitamin, and the animals were kept in a building where the sunlight came in only through common window glass.

The effects of the ration were studied by weighing and measuring the animals at weekly intervals, by analyzing the blood for inorganic phosphorus and calcium, and by analyzing the bones for moisture, extractable material, ash, and the ash for calcium and phosphorus. Data were also taken as to condition of animal, abnormalities, time of showing oestrum, and any other factors which could be attributed to the ration.

Under the conditions of the experiment as outlined, the following conclusions were reached:

Growing dairy animals fed rations low in calcium (0.286 percent or less) or low in both calcium (0.331 percent or less) and phosphorus (0.298 percent or less), but otherwise ample in nutritive value, grow nearly as well as normal-fed animals for some time, but over a period of two years do not make as good gains as measured by weight and height at withers. Animals fed a ration low in phosphorus (0.131 percent) during the second year continued to grow almost as well as did normal-fed animals, even though the inorganic phosphorus content of their blood was much below normal.

The inorganic phosphorus in the blood of growing dairy animals can be more easily reduced than can the calcium content by feeding rations low in these minerals.

Rations containing less than 0.20 percent of phosphorus will decrease the amount of inorganic phosphorus in the blood.

Rations containing as little as 0.25 percent of calcium will not affect the calcium content of the blood.

Growing dairy animals when fed rations low in phosphorus cannot draw sufficient phosphorus from their bones to maintain the normal supply of inorganic phosphorus in the blood.

Rations which contain less than 0.35 percent of calcium or less than 0.20 percent of phosphorus give rise to a bone which is low in ash and consequently low in calcium and phosphorus but high in moisture and extractable material.

The ash of bones contains approximately the same percentage of calcium and phosphorus regardless of the rations fed.

Either the ribs or femurs and humeri can be used for analysis with the same general results.

Rations which are fed under practical conditions may be dangerously near the lower limits of phosphorus requirements.

The analyses of the bones of the animals in the normal group give figures which are fairly representative of the composition of the bones of normal dairy animals at various ages.

LITERATURE CITED

ARMSBY, H P.
1917. THE NUTRITION OF FARM ANIMALS. 747 p. New York.

ARON, H. and SEBAUER, R.
1908. UNTERSUCHUNGEN UEBER DIE BEDEUTUNG DER KALKSALZE FUER DEN WACHSENDEN ORGANISMUS. Biochem. Zeit, 8:1.

ASTON, B. C.
1905. BUSH OF TANGANDA DISEASE. 13th Ann. Rept., N. Zeal. Dept. Agr.: 81.

BELL, R. D., and DOISY, E. A.
1920. RAPID COLORIMETRIC METHOD FOR THE DETERMINATION OF PHOSPHORUS IN URINE AND BLOOD. Jour. Biol. Chem. 44:55.

BETHKE, R. M., STEENBOCK, H., and NELSON, M. T.
1923. FAT SOLUBLE VITAMINS—XV. CALCIUM AND PHOSPHORUS RELATIONS TO GROWTH AND COMPOSITION OF BLOOD AND BONE WITH VARYING VITAMIN INTAKE. Jour. Biol. Chem. 58:71.

BITTING, A. W.
1894. BIG HEAD (OSTEOPOROSIS). Fla. Agr. Expt. Sta. Bul. 26, p. 53-63.

BOHSTEDT, G.
1926. MINERAL AND VITAMIN REQUIREMENTS OF PIGS. Ohio Agr. Expt. Sta. Bul. 395.

———, BETHKE, R. M., EDGINGTON, B. H., and ROBISON, W. L.
1927. MINERALS AND VITAMINS IN RATIONS OF PIGS. Ohio Expt. Sta. bimonthly Bul. 12:67.

BRIGGS, A. P.
1922. A MODIFICATION OF THE BELL-DOISY PHOSPHATE METHOD. Jour. Biol. Chem. 53:13.

———
1924. SOME APPLICATIONS OF THE COLORIMETRIC PHOSPHATE METHOD. Jour. Biol. Chem. 59:255.

CHOSSAT, C.
1842. NOTE SUR LE SYSTEME OSSEUX. Compt. Rend. Acad. des Sci. 14:451. Cited in Ohio Agr. Expt. Sta. Tech. Bul. 5, p. 384.

DAVIS, H. P., MASUROVSKY, B., NEVENS, W. B., WOODWARD, E. G., HENDRICKSON, J. W., and FRANDSEN, J. B.
1922. GROWTH STUDIES OF DAIRY HEIFERS. Neb. Agr. Expt. Sta. Bul. 181.

ECKLES, C. H.
1915. THE RATION AND AGE OF CALVING AS FACTORS INFLUENCING THE GROWTH AND DAIRY QUALITIES OF COWS. Mo. Agr. Expt. Sta. Bul. 135.
———, and SWETT, W. W.
1918. SOME FACTORS INFLUENCING THE RATE OF GROWTH AND SIZE OF DAIRY HEIFERS AT MATURITY. Mo. Agr. Expt. Sta. Res. Bul. 31.
———
1920. THE NORMAL GROWTH OF DAIRY CATTLE. Mo. Agr. Expt. Sta. Res. Bul. 36.
———, BECKER, R. B., and PALMER, L. S.
1926. A MINERAL DEFICIENCY IN THE RATIONS OF CATTLE. Minn. Agr. Expt. Sta. Bul. 229.
FORBES, E. B., BEEGLE, F. M., and MENSCHING, J. E.
1913. MINERAL AND ORGANIC ANALYSES OF FOODS. Ohio Agr. Expt. Sta. Bul. 255, p. 225-231.
———, ———, FRITZ, C. M., MORGAN, L. E., and RHUS, S. N.
1916. THE MINERAL METABOLISM OF THE MILCH COW. FIRST PAPER. Ohio Agr. Expt. Sta. Bul. 295.
———, ———, ———, ———
1917. THE MINERAL METABOLISM OF THE MILCH COW. II. Ohio Agr. Expt. Sta. Bul. 308.
———, HALVERSON, J. O., and MORGAN, L. E.
1918. THE MINERAL METABOLISM OF THE MILCH COW. III. Ohio Agr. Expt. Sta. Bul. 330.
———, HUNT, C. H., SCHULZ, J. A., WINTER, A. R., and REMLER, R. F.
1922. THE MINERAL METABOLISM OF THE MILCH COW. Ohio Agr. Expt. Sta. Bul. 363.
———, SCHULZ, J. A., HUNT, C. H., WINTER, A. R., and REMLER, R. F.
1922a. MINERAL METABOLISM OF THE MILK COW. Jour. Biol. Chem. 52:281.
FORSTER, J. M.
1873. VERSUCHE UEBER DIE BEDEUTUNG DER ASCHENBESTANDTHEILE IN DER NAHRUNG. Zeit. Biol. 9:297.
GOHREN, F. VON.
1861. UEBER EINE BEIGABE VON KNOCHENERDE ZUM FUTTER DER THIERE NEBST EINEM PHYSIOLOGISCH-CHEMISCHEN VERSUCH UEBER DEREN VERDAULICHKEIT. Landw. Vers. Sta. 3:161-171.
GULLICKSON, T. W., and ECKLES, C. H.
1927. THE RELATION OF SUNLIGHT TO THE GROWTH AND DEVELOPMENT OF CALVES. Jour. Dairy Sci. 10:87.
HAAG, J. R., and PALMER, L. S.
1928. THE EFFECT OF VARIATIONS IN THE PROPORTIONS OF CALCIUM, MAGNESIUM, AND PHOSPHORUS CONTAINED IN THE DIET. Jour. Biol. Chem. 74:367.
HALVERSON, J. O., MOHLER, H. K., and GORGEIN, O.
1917. THE CALCIUM CONTENT OF THE BLOOD SERUM IN CERTAIN PATHOLOGICAL CONDITIONS. Jour. Biol. Chem. 32:171.
———, and NIXON, L. M.
1924. THE CALCIUM REQUIREMENT OF ANIMALS IN RELATION TO THE CALCIUM CONTENT OF FEEDS. N. Car. Dept. Agr. Bul. June, 1924, p. 430-431.
HAMMETT, F. S.
1925. A BIOCHEMICAL STUDY OF BONE GROWTH: I. CHANGES IN THE ASH, ORGANIC MATTER, AND WATER DURING GROWTH. Jour. Biol. Chem. 64:409.
———
1925a. A BIOCHEMICAL STUDY OF BONE GROWTH: II. CHANGES IN THE CALCIUM, MAGNESIUM, AND PHOSPHORUS OF BONE DURING GROWTH. Jour. Biol. Chem. 64:685.

———
1925b. A BIOCHEMICAL STUDY OF BONE GROWTH: III. CHANGES IN THE COMPOSITION OF THE ASH DURING GROWTH. Jour. Biol. Chem. 64:693.

HART, E. B., MCCOLLUM, E. V., and FULLER, J. G.
1909. THE ROLE OF INORGANIC PHOSPHORUS IN THE NUTRITION OF ANIMALS. Wis. Agr. Expt. Sta. Res. Bul. 1.

———, HALPIN, J. G., and STEENBOCK, H.
1920. USE OF SYNTHETIC DIETS IN THE GROWTH OF BABY CHICKS. Jour. Biol. Chem. 43.

———, STEENBOCK, H., and HOPPERT, C. A.
1921. I. THE COMPARATIVE INFLUENCE OF GREEN AND DRIED PLANT TISSUE, CABBAGE, ORANGE JUICE, AND COD-LIVER OIL ON CALCIUM ASSIMILATION. Jour. Biol. Chem. 48:33.

———, ———, ———, BETHKE, R. M., and HUMPHREY, G. C.
1922. III. THE COMPARATIVE EFFICIENCY OF TIMOTHY HAY, ALFALFA HAY, AND TIMOTHY PLUS CALCIUM PHOSPHATE IN MAINTAINING CALCIUM AND PHOSPHORUS EQUILIBRIUM IN MILKING COWS. Jour. Biol. Chem. 54:75.

———, ———, ———, and HUMPHREY, G. C.
1923. DIETARY FACTORS INFLUENCING CALCIUM ASSIMILATION: IV. THE COMPARATIVE EFFICIENCY OF MIXED GREEN GRASSES AND THE SAME MIXTURE PLUS STEAMED BONEMEAL IN MAINTAINING CALCIUM AND PHOSPHORUS EQUILIBRIUM IN MILKING COWS. Jour. Biol. Chem. 58:43.

———, ———, ———, ———
1923a. II. THE COMPARATIVE EFFICIENCY OF DRY AND GREEN ALFALFA IN MAINTAINING CALCIUM AND PHOSPHORUS EQUILIBRIUM IN MILKING COWS. Jour. Biol. Chem. 53:21.

———, ———, and ELVEHJEM, C. A.
1924. DIETARY FACTORS AFFECTING CALCIUM ASSIMILATION: V. THE EFFECT OF LIGHT UPON CALCIUM AND PHOSPHORUS EQUILIBRIUM IN MATURE LACTATING ANIMALS. Jour. Biol. Chem. 62:117.

———, ———, HUMPHREY, G. C., and HULCE, R. S.
1924. NEW OBSERVATIONS AND A NEW INTERPRETATION OF OLD OBSERVATIONS ON THE NUTRITIVE VALUE OF THE WHEAT PLANT. Jour. Biol. Chem. 62:315.

———, BEACH, B. A., DELWICHE, E. J., and BAILEY, E. G.
1927. PHOSPHORUS DEFICIENCY AND A DAIRY CATTLE DISEASE. Wis. Agr. Expt. Sta. Bul. 389.

HENRY, W. A., and MORRISON, F. B.
1923. FEEDS AND FEEDING. Ed. 18. 770 p. Madison.

HESS, A. F., PAPPENHEIMER, A. M., and WEINSTOCK, M.
1922. A STUDY OF LIGHT WAVES IN RELATION TO THEIR PROTECTIVE ACTION IN RICKETS. Soc. Exp. Biol. and Med. Proc. 20:14-16.

JORDAN, W. H., HART, E. B., and PATTEN, A. J.
1906. A STUDY OF THE METABOLISM AND PHYSIOLOGICAL EFFECT OF CERTAIN PHOSPHORUS COMPOUNDS WITH MILK COWS. N. Y. Agr. Expt. Sta. Tech. Bul. 1.

KELLNER, O.
1907. DIE ERNAHRUNG DER LANDWIRTSCHAFTLICHEN NUTZTIERE. Ed. 4. Berlin. Cited in Ohio Expt. Sta. Tech. Bul. 5, p. 421.

KRUGER, J. H., and BECHDEL, S. I.
1928. STUDIES IN THE NORMAL DEPOSITIONS OF MINERALS IN THE BONES OF DAIRY CALVES. Jour. Dairy Sci. 11:24.

MARCQ, J.
1925. NUTRITIVE VALUE OF PHOSPHORUS IN CATTLE FEEDING. Intern. Rev. Sci. Practice Agr. 3:58-64. Cited in Chem. Abst. 19:2690.

MAYNARD, L. A., GOLDBERG, S. A., and MILLER, R. C.
1925. A STUDY OF THE DIETARY RELATIONSHIP AND THE PATHOLOGY OF STIFFNESS IN SWINE. Cornell Memoir, 86.

MEIGS, E. B., BLATHERWICK, N. R., and CARY, C. A.
1919. CONTRIBUTIONS TO THE PHYSIOLOGY OF PHOSPHORUS AND CALCIUM METABOLISM AS RELATED TO MILK SECRETION. Jour. Biol. Chem. 37:1.

———, and WOODWARD, T. E.
1921. INFLUENCE OF CALCIUM AND PHOSPHORUS IN THE FEED ON THE MILK YIELD OF DAIRY COWS. Jour. Dairy Sci. 4:185.

MELLANBY, E.
1919. AN EXPERIMENTAL INVESTIGATION ON RICKETS. Lancet: March 15, p. 407.

MCCANDLISH, A. C.
1923. STUDIES IN THE GROWTH AND NUTRITION OF DAIRY CALVES: VI. THE ADDITION OF HAY AND GRAIN TO A MILK RATION FOR CALVES. Jour. Dairy Sci. 6:347-372.

MCCOLLUM, E. V., SIMMONDS, N., SHIPLEY, P. G., and PARK, E. A.
1921. THE EFFECTS ON GROWING RATS OF DIETS DEFICIENT IN CALCIUM. Amer. Jour. Hyg. 1:492.

———, ———, ———, ———
1921a. VII. THE PRODUCTION OF RICKETS BY DIETS LOW IN PHOSPHORUS AND FAT-SOLUBLE A. Jour. Biol. Chem. 47:507.

———, ———, and BECKER, J. E.
1922. AN EXPERIMENTAL DEMONSTRATION ON THE EXISTENCE OF A VITAMIN WHICH PROMOTES CALCIUM DEPOSITION. Jour. Biol. Chem. 53:293.

———, ———, KINNEY, M., SHIPLEY, P. G., and PARK, E. A.
1922a. STUDIES ON EXPERIMENTAL RICKETS: XVII. THE EFFECTS OF DIETS DEFICIENT IN CALCIUM AND IN FAT-SOLUBLE A IN MODIFYING THE HISTOLOGICAL STRUCTURE OF THE BONES. Amer. Jour. Hyg. 2:97.

———, ———
1927. THE NEWER KNOWLEDGE OF NUTRITION. Ed. 3. 655 p., illus. New York.

MOULTON, C. R., TROWBRIDGE, P. F., and HAIGH, L. D.
1918. STUDIES IN ANIMAL NUTRITION: I. CHANGES IN FORM AND WEIGHT ON DIFFERENT PLANES OF NUTRITION. Mo. Agr. Expt. Sta. Res. Bul. 43.

MURPHY, E. W.
1917. TREATMENT OF PASTURES. PREVENTION OF RICKETS, CRIPPLES, AND PARALYSIS. Jour. Dept. Agr. Victoria 15:449-456. Cited in Minn. Agr. Expt. Sta. Bul. 229.

NESSLER, J.
1873. II. UNTERSUCHUNGEN DER KNOCHEN VON KNOCHENBRUCHIGKEITEM RINDVIEH. Landw. Vers. Sta. 16:187.

OSBORNE, T. B., and MENDEL, L. B.
1918. THE INORGANIC ELEMENTS IN NUTRITION. Jour. Biol. Chem. 34:131.

PEARSON, L.
1898. ABNORMAL (DEPRAVED) APPETITE IN CATTLE. Pa. Dept. Agr. Bul. 34: 131-132.

REED, O. E., FITCH, J. B., and CAVE, H. W.
1924. THE RELATION OF FEEDING AND AGE OF CALVING TO THE DEVELOPMENT OF DAIRY HEIFERS. Kans. Agr. Exp. Sta. Bul. 233.

———, and HUFFMAN, C. F.
1925. THE IMPORTANCE OF WELL-CURED HAY IN THE RATION OF DAIRY CATTLE. Holstein-Friesian World, 23:8.

———, ———
1928. PHOSPHORUS FOR DAIRY CATTLE. Hoard's Dairyman 73:618.

ROSE, A. R.
1912. A STUDY OF THE METABOLISM AND PHYSIOLOGICAL EFFECTS OF CERTAIN PHOSPHORUS COMPOUNDS WITH MILK COWS. N. Y. Agr. Expt. Sta. Tech. Bul. 20.

SALMON, W. D., and EATON, W. H.
1925. EFFECT OF BONEMEAL ON GROWTH OF DAIRY HEIFERS. Jour. Dairy Sci. 8:312-917.

SCHMIDT, H.
1924. FIELD AND LABORATORY NOTES ON A FATAL DISEASE OF CATTLE OCCURRING ON THE COASTAL PLAINS OF TEXAS (LOIN DISEASE). Texas Agr. Expt. Sta. Bul. 319.

SHERMAN, H. C., and PAPPENHEIMER, A. M.
1921. A DIETETIC PRODUCTION OF RICKETS IN RATS AND ITS PREVENTION BY INORGANIC SALTS. Proc. Soc. Exp. Biol. and Med. 18:193.

STEENBOCK, H., HART, E. B., JONES, J. H., and BLACK, A.
1923. FAT-SOLUBLE VITAMINES: XIV. THE INORGANIC PHOSPHORUS AND CALCIUM OF THE BLOOD USED AS CRITERIA IN THE DEMONSTRATION OF THE EXISTENCE OF A SPECIFIC ANTIRACHITIC VITAMIN. Jour. Biol. Chem. 58:59.

THEILER, A.
1920. THE CAUSE AND PREVENTION OF LAMZIEKTE. Jour. Dept. Agr. Union of S. Afr. 1:221-247.

———, GREEN, H. H., and DU TOIT, P. J.
1924. PHOSPHORUS IN THE LIVESTOCK INDUSTRY. Jour. Dept. Agr., Union of S. Afr. 8:460-504.

TROWBRIDGE, P. F., MOULTON, C. R., and HAIGH, L. D.
1915. THE MAINTENANCE REQUIREMENT OF CATTLE AS INFLUENCED BY CONDITION, PLANE OF NUTRITION, AGE, SEASON, TIME ON MAINTENANCE, TYPE, AND SIZE OF ANIMAL. Mo. Agr. Expt. Sta. Res. Bul. 18.

———, ———, ———
1918. EFFECT OF LIMITED FOOD SUPPLY ON THE GROWTH OF YOUNG BEEF ANIMALS. Mo. Agr. Expt. Sta. Res. Bul. 28.

TUFF, P.
1924. OSTEOMALACIA AND ITS OCCURRENCE IN CATTLE IN NORWAY. Proc. World's Dairy Congress 2:1494.

VOIT, E.
1880. UEBER DIE BEDEUTUNG DES KALKES FUER DEN THIERISCHEN ORGANISMUS. Zeit. Biol. 16:55.

WEISKE, H.
1872. UEBER DEN EINFLUSS VON KALK ODER PHOSPHORSAEURFARME NAHRUNG AUF DIE ZUSAMMENSETZUNG DER KNOCHEN. Landw. Vers. Sta. 15:152.

———, and WILDT, E.
1873. UNTERSUCHUNGEN UEBER DIE ZUSAMMENSETZUNG DER KOCHEN BEI KALK ODER PHOSPHORSAEUREN NAHRUNG. Zeitschr. Biol. 9:541-547.

WELCH, H.
1924. BONE-CHEWING BY CATTLE. Montana Agr. Expt. Sta. Circ. 122.

TABLE OF CONTENTS

	PAGE
Introduction	3
Review of Literature	4
Methods Employed in the Experiment	5
Description of Animals Fed	6
Housing and Care of the Animals	7
Exercise	8
Bedding	8
Weighing and Measuring	8
Breeding	8
Salting	8
Water	8
Methods of Feeding	9
Early Feeding	9
Analysis of Rations	9
Rations	10
Calcium and Phosphorus Content of the Ration	11
Discussion of the Rations Fed	13
Amount of Phosphorus and Calcium Fed	13
Ratio of Calcium and Phosphorus	15
Factor Which Assists in the Assimilation of Calcium and Phosphorus	15
Results of the Experiment	17
Effects of Rations on Growth and Development of the Animals	17
Growth	17
Discussion of Results	19
Physical Abnormalities	21
Abnormal Cravings	23
Drinking Habits	23
Effect of Rations upon the Oestrum of the Animals	24
Discussion of Results	25
Effect of Rations upon the Calcium and Inorganic Phosphorus Content of the Blood	27
Analyses of Blood	27
Calcium	27
Phosphorus	28
Study of Individuals	29
Discussion of Results	30
Effect of the Rations upon the Bones of the Animals	33
Effect of Composition	33
Sampling the Bones	33
Method of Analysis	33
Analysis of Ribs	34
Analysis of Femur and Humerus	36
Discussion of Results	37
Effect on Appearance	41
Effect on Breaking Strength	43
Summary	44
Effect of Rations upon Internal Organs and Dressing Percentage	45
General Discussion of Results	46
Summary and Conclusions	50
Literature Cited	51

Bulletin 232 April, 1930

Wintering Dairy Heifers by Means of the Self-Feeder

by H. O. HENDERSON and E. L. ANTHONY

A Typical Self-fed Heifer (No. 81) A Typical Hand-fed Heifer (No. 84)

UNIVERSITY OF LIBRARY

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

AGRICULTURAL EXPERIMENT STATION STAFF

JOHN R. TURNER, Ph. D., LL. D. ..... President of the University
F. D. FROMME, Ph. D. ..... Dean and Director
GERALD JENNY, M. S. ..... Agricultural Editor
JOHN C. JOHNSTON ..... Chief Clerk

AGRONOMY AND GENETICS

R. J. Garber, Ph. D.
Agronomist and Geneticist
E. P. Deatrick, Ph. D.
Associate Agronomist
W. H. Pierre, Ph. D.
Associate Agronomist
T. C. McIlvaine, Ph. D.†
Assistant Agronomist
D. R. Dodd, B. S.‡
Assistant Agronomist
M. M. Hoover, M. S.
Assistant Agronomist
H. K. Rowley, M. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, D. Sc.
Animal Husbandman
Chas. V. Wilson, M. S.
Assistant Animal Husbandman
J. H. Longwell, M. A.
Assistant Animal Husbandman
J. H. Rietz, D. V. M.
Associate Veterinarian
R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman
R. S. Glasscock, M. S.**
Assistant in Veterinary Science

CHEMISTRY

R. B. Dustman, Ph. D.
Agricultural Chemist
Chas. E. Weakley, Jr., B. A.
Assistant Chemist
L. P. Hansen, Ph. D.
Assistant Chemist
T. B. Leith, M. S.**
Assistant Chemist
Leland Shriver, M. S. Ch. E.
Assistant in Agricultural Chemistry

DAIRY HUSBANDRY

H. O. Henderson, Ph. D.
Dairy Husbandman
L. M. Thurston, Ph. D.
Assistant Dairy Husbandman
K. S. Morrow, M. S.
Assistant Dairy Husbandman
L. F. Sutton, B. S. Agr.††
Assistant Dairy Husbandman
R. A. Ackerman, B. S.
Assistant in Dairy Husbandry

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist
W. E. Rumsey, B. S.**
State Entomologist
Edwin Gould, B. S. Agr.
Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist
F. D. Cornell, Jr., M. S.
Assistant Farm Mechanician
W. W. Armentrout, M. S.
Assistant Farm Economist
R. O. Stelzer, B. S.
Assistant in Farm Economics

HOME ECONOMICS

Rachel H. Colwell, M. A.
Home Economist
Hazel C. Cameron, M. A.
Research Specialist in Nutrition

HORTICULTURE

H. E. Knowlton, Ph. D.
Horticulturist
K. C. Westover, M. S. Agr.
Assistant Horticulturist
F. W. Craig, M. S. Agr.**
Assistant Horticulturist
M. B. Hoffman, M. S.
Assistant in Horticulture
E. N. McCubbin, M. A.
Assistant in Horticulture
A. P. Dye, M. S. Agr.
Assistant in Horticulture

PLANT PATHOLOGY

C. R. Orton, Ph. D.
Plant Pathologist
Anthony Berg, M. S.
Associate Plant Pathologist
L. H. Leonian, Ph. D.
Associate Plant Pathologist
F. J. Schneiderhan, M. S.
Associate Plant Pathologist
E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr.
Poultry Husbandman
T. B. Clark, B. S. Agr.
Assistant in Poultry Husbandry

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-Station, Lakin, W. Va.
‡Resigned, February, 1930.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
††In charge of the Reymann Memorial Farms, Wardensville, W. Va.

*The Use of the Self-Feeder in Wintering Dairy Heifers**

by H. O. HENDERSON and E. L. ANTHONY†‡

THE use of a self-feeder in the feeding of livestock first received wide-spread approval among hog feeders in the Central West. The high cost of raising heifers to replace the dairy cows which for various reasons are removed from the dairy herd presents a real economic problem, and any practice which will reduce this cost or add to the success of calf raising, if adopted, would effect a real saving to the dairy cattle industry. It would seem, therefore, that the self-feeder scheme might offer definite advantages in the problem of raising replacement heifers.

REVIEW OF LITERATURE

The use of the self-feeder in the feeding of calves, heifers, and even milking cows has been tried in a limited way at various agricultural experiment stations. The Nebraska Station *(6)* fed one group of calves under 6 months of age by means of the self-feeder, while another group was fed hay and grain twice a day in the usual manner. It was found that the self-fed heifers consumed large amounts of grain as compared to the hand-fed heifers but at the same time made much more rapid gains in weight. The total digestible nutrients required for one pound of gain in weight was less with the self-fed heifers than with the hand-fed heifers. There was also a material saving in the amount of labor required to care for the self-fed heifers as compared with the hand-fed heifers.

The Montana Station *(1)*, *(9)* in a similar experiment with calves under 6 months of age found that very large gains in live weight may be attained by the use of self-feeders, but that just as good gains can be made with hand-fed calves if good feeding is practised. It was concluded that self-feeders for growing dairy calves have no merits over hand-feeding.

At the Iowa Station *(3)*, *(5)* it was found that calves fed by means of the self-feeder consumed a ration of much narrower nutritive ratio than is generally recommended. It was also found that dairy calves can be fed economically until 6 months of age with a self-fed mixture of cracked corn, ground oats, wheat bran, and linseed oilmeal.

*Submitted for publication May, 1929.

†Warren Gifford, assistant professor of dairy husbandry, University of Missouri, also assisted with the experiment during 1923-1925.

‡Mr. Anthony resigned in September, 1928.

The South Dakota Station *(8)* found that the self-feeder was not an efficient method of raising calves, for the calves consumed too much of high-protein materials, thus making a very expensive ration. In this experiment growing calves were not able to select to the best advantage the proper feeds for themselves.

All of these experiments were conducted with calves up to 6 months of age. The Iowa Station *(4)*, however, raised one group of 3 calves from birth until two years of age on the self-feeder. These calves were given access to a hopper which contained shelled corn, cracked corn, whole oats, ground oats, wheat bran, and linseed oil-meal. They were allowed to run in a small pasture during the summer months for their roughage, but had access to the grain at all times. Very little difference was noted in the feed cost of raising heifers to two years of age by the self-feeder method, or by hand-feeding if a liberal grain allowance was given. The feed cost per pound of gain was lower with the self-fed heifers. It was found also that the heifers raised on the self-feeders showed the greatest increase in live weight, height, depth, and width.

The self-feeder has also been tried with milking cows *(2)*, *(7)*, but with poor results. The cows consumed much more than was required for their maintenance and milk production, while the milk yield was not appreciably increased. The cows tended to lay on additional weight, thus increasing the maintenance cost.

As far as can be determined, no experiments have been tried to ascertain the practicability of wintering heifers by means of the self-feeder and by turning them on pasture during the summer months without additional feed. The cost of caring for such heifers would evidently be considerably less. If a method could be evolved which would enable dairymen to reduce the customary labor of two years' feeding necessary before a heifer comes into milk, or which would reduce the winter feeding to one year, or which would bring heifers to a state of maturity whereby more nearly 100 percent mature production could be obtained with the first calf, important economic savings would result. To determine if such results could be obtained an experiment was started at the West Virginia Station on the use of the self-feeder, employing different groups of dairy calves and heifers. Results were obtained for 3 trials. The first two trials included only heifers during their second year, while in the third trial calves were put on the experiment at about 4 months of age, and the results of two years' feeding were included. The results obtained from these trials are presented in this bulletin.

PLAN OF EXPERIMENT

The experiment was conducted for the 3 periods 1921-22, 1923-24, and 1923-25. Two groups of heifers were used during each trial. One group was fed during the winter months a ration as near to its requirements as was practicable and in some cases even slightly below requirement, as stated by the Morrison Feeding Standard, while the animals in the other groups were fed all the roughage they

TABLE 1.—*Breed, Age, and Size of Heifers Used in the First Trial, 1921-22, at the Beginning of the Trial*

No. of Heifer	Breed	Age			Size	
		Yrs.	Mos.	Days	Weight *(pounds)*	Height at Withers *(centimeters)*
GROUP I. (SELF-FED)						
39	Holstein	1	2	14	675	132.0
41	Holstein	1	1	7	525	123.2
44	Jersey		11	7	450	111.8
45	Holstein		9	25	535	125.7
Average		1	0	3	546	123.2
GROUP II. (HAND-FED)						
32	Guernsey	1	7	10	610	122.0
40	Holstein	1	2	0	655	132.2
42	Holstein	1	0	25	505	116.8
46	Holstein		8	6	530	119.5
Average		1	1	16	575	122.6

would consume and were given access to a hopper which was kept filled with cornmeal, wheat bran, and linseed oilmeal. As soon as pasture season arrived (usually about May 5 to 10) all of the heifers from both groups were turned on a large pasture (about 75 acres). The pasture was fairly good until late summer, when it would become quite short and dry. With the early fall rains the pasture would improve and would again give fair yield until late fall (usually about November 20 to 25), after which the heifers would be put into the stable.

In the stable the heifers were housed in large open sheds. They were not tied, but were allowed to go and come as they desired. Some trouble was experienced in keeping the larger heifers from fighting the smaller ones. This was especially true in the case of the hand-fed groups, but since the group as a whole was considered rather than the individual, this circumstance should affect the results but

TABLE 2.—*Breed, Age, and Size of Heifers Used in the Second Trial, 1923-24, at the Beginning of the Trial*

No. of Heifer	Breed	Age			Size	
		Yrs.	Mos	Days	Weight *(pounds)*	Height at Withers *(centimeters)*
GROUP III. (SELF-FED)						
71	Holstein	1	5	11	721.5	129.5
73	Holstein	1	3	7	605	124.5
81	Holstein	1	0	3	471	116.8
83	Holstein		10	2	381.5	112.0
86	Guernsey		8	18	300	102.0
Average		1	0	18	495.8	116.9
GROUP IV. (HAND-FED)						
70	Holstein	1	5	11	721.5	129.5
72	Holstein	1	3	29	596	120.2
77	Holstein	1	1	28	567.5	122
84	Holstein		9	28	385	116.5
85	Guernsey		9	16	295	104
Average		1	1	9	513	118.4

little. The self-fed groups were fed concentrates in the self-feeder and were allowed free access to roughage. Records were kept of the feed consumed as well as of feed wasted. Salt and water were kept before the animals of each group at all times.

Each group was weighed and the height at the withers was measured every two weeks during the winter months and at monthly intervals during the summer months. A record was kept of the amount of feed consumed by each group.

Tables 1, 2, and 3 give breed, age, and size of the heifers at the beginning of the experiment.

TABLE 3.—*Breed, Age, and Size of Heifers Used in the Third Trial, 1923-25, at the Beginning of the Trial*

No. of Heifer	Breed	Age		Size	
		Mos.	Days	Weight *(pounds)*	Height at Withers *(centimeters)*
GROUP V. (SELF-FED)					
111	Holstein	4	16	320	109.0
113	Jersey	3	28	230	95.7
114	Ayrshire	3	20	255	98.3
116	Holstein	2	29	290	100.3
Average		3	26	274	100.8
GROUP VI. (HAND-FED)					
109	Holstein	5	7	350	103.5
110*	Jersey	4	24	240	95.7
112	Holstein	4	17	262	100.5
115	Jersey	3	12	210	90.5
141	Ayrshire	11	18	490	109
Average (Omitting No. 141)		4	15	265	97.5

*No. 110 died of paint-poisoning in July, 1924, and No. 141 was put in her place for the second year's work beginning Nov. 15, 1924.

METHOD OF FEEDING

Feeding during First Trial.—In Trial I, which started on November 24, 1921, each group was fed daily 6 pounds of alfalfa hay per head and 3 pounds of corn silage for each 100 pounds of live weight. In addtion Group I was allowed free access to a hopper filled with wheat bran, cornmeal, and linseed oilmeal. On December 13 the amount of silage fed to Group I was decreased to 1½ pounds per hundred-weight, which was as much as they would consume.

The heifers in Group II were fed an average of 5 pounds per head daily of a grain mixture consisting of 300 pounds of wheat bran, 200 pounds of cornmeal, and 150 pounds of linseed oilmeal.

The average daily amount of feed, digestible protein, total digestible nutrients, and net energy consumed by the heifers in Groups I and II and the amount required as calculated from the Morrison Feeding Standard is given in Table 4.

This table shows that the self-fed group daily consumed 1.794 pounds of digestible protein and 5.425 pounds of total digestible nutrients more than they would have required if on the basis of the recognized feeding standards. Each also consumed daily 1.499

pounds of protein and 5.863 pounds of digestible nutrients more than did the heifers in the hand-fed group. The hand-fed group was fed almost the exact amount of feed as required by the feeding standard.

Feeding during Second Trial—In Trial II, begun December 1, 1923, each group was started with 30 pounds of mixed hay and 30 pounds of corn silage per day. This amount was varied according to the appetites of the heifers. The animals in the self-fed group would not consume this amount, while those in the hand-fed group consumed a larger amount as they grew older.

As in Trial I, Group III, the self-fed group, was allowed free access to a hopper filled with cornmeal, linseed oilmeal, and wheat bran, while Group IV, the hand-fed group, was fed a ration consisting of 300 pounds of wheat bran, 200 pounds of cornmeal, and 150 pounds of linseed oilmeal. This mixture was fed in amounts so that the heifers were receiving nearly a balanced ration according to the feeding standards.

The average amount of feed, digestible protein, total digestible nutrients, and net energy consumed by each group per day as compared to the amount required is given in Table 5. This table shows

TABLE 4.—*Average Amount of Digestible Protein, Total Digestible Nutrients, and Net Energy Consumed Daily by Heifers in Groups I and II of Trial I, as Compared to Their Requirements*

Average Amount of Feed Consumed Per Heifer	Analyses		
	Digestible Protein *(pounds)*	Tot. Dig. Nutrients *(pounds)*	Therms Net Energy
GROUP I. (SELF-FED)			
9.1 pounds corn silage contains	0.100	1.611	1.446
6.0 pounds alfalfa hay contains	0.636	3.096	2.054
15.1 pounds roughage contains	0.736	4.707	3.500
5.42 pounds cornmeal contains	0.385	4.420	4.769
4.90 pounds linseed oilmeal contains	1.490	3.817	4.361
3.48 pounds wheat bran contains	0.435	2.119	1.844
13.80 pounds grain contains	2.310	10.356	10.974
Total ration contains	3.046	15.163	14.474
Requirements of 695.6-pound heifer	1.252	9.738	
Daily amount fed in excess of requirements	1.794	5.425	
GROUP II. (HAND-FED)			
15 pounds corn silage contains	0.165	2.655	2.385
6 pounds alfalfa hay contains	0.636	3.096	2.054
21 pounds roughage contains	0.801	5.751	4.439
1.55 pounds cornmeal contains	0.109	1.258	1.355
1.15 pounds linseed oilmeal contains	0.352	0.896	1.023
2.30 pounds wheat bran contains	0.286	1.395	1.214
5 pounds grain contains	0.746	3.549	3.592
Total ration contains	1.547	9.300	8.031
Requirements of 677.5-pound heifer	1.230	9.485	
Daily amount fed in excess of requirements	0 317	0.185	

TABLE 5.—*Average Amount of Feed, Digestible Protein, Total Digestible Nutrients, and Net Energy Consumed Daily by Heifers in Groups III and IV of Trial II, as Compared to Their Requirements*

Average Amount of Feed Consumed Per Heifer	Analyses		
	Digestible Protein *(pounds)*	Tot. Dig. Nutrients *(pounds)*	Therms Net Energy
GROUP III. (SELF-FED)			
6.70 pounds corn silage contains	0.744	1.186	1.065
3.86 pounds mixed hay contains	0.154	1.783	1.579
10.56 pounds roughage contains	0.228	2.969	2.644
0.31 pounds cornmeal contains	0.022	0.253	0.273
6.76 pounds linseed oilmeal contains	2.075	5.266	6.016
7.99 pounds wheat bran contains	0.999	4.866	4.235
15.06 pounds grain contains	3.096	10.385	10.524
Total ration contains	3.324	13.354	13.168
Requirements of 659-pound heifer	1.186	9.226	
Daily nutrients consumed in excess of requirements	2.238	4.128	
GROUP IV. (HAND-FED)			
12.26 pounds corn silage contains	0.135	2.170	1.949
7.46 pounds mixed hay contains	0.298	3.447	3.051
19.72 pounds roughage contains	0.433	5.617	5.000
1.15 pounds cornmeal contains	0.082	0.939	1.012
0.86 pounds linseed oilmeal contains	0.263	0.670	0.765
1.73 pounds wheat bran contains	0.216	1.054	0.917
3.84 pounds grain contains	0.561	2.663	2.694
Total ration contains	0.994	8.280	7.694
Requirements of 609.6-pound heifer	1.097	8.534	
Daily amount consumed less than requirements	−0.103	−0.254	

that each heifer in the self-fed group daily consumed 2.238 pounds of digestible protein and 4.128 pounds of total digestible nutrients more than they required. They consumed on the average 11.22 pounds more grain but 9.16 pounds less roughage per day than did the heifers in the hand-fed group. Each animal also consumed 2.330 pounds of digestible protein and 4.382 pounds of total digestible nutrients more per day than did the heifers in Group IV, which was fed by hand. The heifers in Group IV were fed slightly less of both digestible protein and total digestible nutrients than their requirements.

Feeding during Third Trial —Trial III was started December 21, 1923, although one calf in each group was not put in the experiment until January 16, 1924. This experiment continued throughout two years. The calves during the first feeding period were much younger than those in Trials I and II. The calves in both groups had been fed skimmilk up until the time they were put on the experiment and for some time afterward. However, just as soon as they became accustomed to eating grain and roughage, the milk was discontinued.

Both groups were fed all the corn silage and alfalfa hay they

would eat. For some time soybean hay was fed instead of alfalfa hay. Group V was allowed free access to a hopper filled with cornmeal, wheat bran, ground oats, and linseed oilmeal, while Group VI was fed, according to its requirements, a ration consisting of 300 pounds of cornmeal and 100 pounds each of wheat bran, ground oats, and linseed oilmeal.

Table 6 gives the average amount of feed, digestible protein, digestible nutrients, and net energy consumed by the heifers of each group per day as compared to the amount required. This is for the first feeding period.

Table 6 shows that during the first year the heifers in the self-fed group (Group V) each consumed on the average 2.208 pounds of digestible protein and 4.114 pounds of total nutrients more than is called for by the feeding standard. Each also consumed daily 8.27 pounds of grain, and 2.08 pounds of digestible protein, 4.478 pounds of total nutrients, and 5.142 therms net energy more than the heifers

TABLE 6.—*Average Amount of Feed, Digestible Protein, Digestible Nutrients, and Net Energy Consumed Daily by Heifers in Groups V and VI of Trial III during the First Feeding Period, as Compared to Their Requirements*

Average Amount of Feed Consumed Per Heifer	Analyses		
	Digestible Protein *(pounds)*	Tot. Dig. Nutrients *(pounds)*	Therms Net Energy
GROUP V. SELF-FED GROUP (FIRST WINTER-FEEDING PERIOD)			
5.38 pounds corn silage contains	0.059	0.952	0.855
0.80 pounds soybean hay contains	0.093	0.429	0.352
3.06 pounds alfalfa hay contains	0.324	1.579	1.047
9.24 pounds roughage contains	0.476	2.960	2.254
0.95 pounds cornmeal contains	0.067	0.776	0.836
5.15 pounds linseed oilmeal contains	1.576	4.012	4.584
4.12 pounds wheat bran contains	0.515	2.509	2.184
0.51 pounds ground oats contains	0.495	0.495	0.347
10.73 pounds grain contains	2.653	7.792	7.951
Total ration contains	3.129	10.752	10.205
Requirements of 428.3-pound heifer	0.921	6.638	
Daily amount consumed in excess of requirements	2.208	4.114	
GROUP VI. HAND-FED GROUP (FIRST WINTER-FEEDING PERIOD)			
5.90 pounds corn silage contains	0.065	1.044	0.938
1.14 pounds soybean hay contains	0.133	0.611	0.502
5.13 pounds alfalfa hay contains	0.548	2.647	1.754
12.17 pounds roughage contains	0.746	4.302	3.194
1.23 pounds cornmeal contains	0.077	1.005	1.008
0.41 pounds linseed oilmeal contains	0.125	0.319	0.365
0.41 pounds wheat bran contains	0.051	0.250	0.217
0.41 pounds ground oats contains	0.040	0.398	0.279
2.46 pounds grain contains	0.303	1.972	1.869
Total ration contains	1.049	6.274	5.063
Requirements of 345-pound heifer	0.845	5.692	
Daily amount consumed in excess of requirement	0.204	0.582	

in the hand-fed group (Group VI). The calves in Group VI were fed just a little above their requirements.

Both of these groups were turned on pasture during the summer, but when brought into the barn in the fall of 1924 they again were put on the experiment (Nov. 20, 1924). Group V again was fed all of the roughage the animals would eat and given free access to a hopper filled with cornmeal, linseed oilmeal, and wheat bran. Group VI was fed a good supply of roughage and a grain ration consisting of 300 pounds of wheat bran, 200 pounds of cornmeal, and 150 pounds of linseed oilmeal.

Table 7 gives the average amount of feed, digestible protein, digestible nutrients, and net energy consumed daily by each heifer in each group as compared to the amount required during the second winter. This table shows that during the second feeding period of Trial III the heifers in Group V consumed 2.246 pounds of digestible protein and 7.03 pounds of digestible nutrients more per day than their requirements. The heifers in Group VI on the other hand were fed just a little above their requirements for digestible protein, but received 1.783 pounds of digestible nutrients less on the average than

TABLE 7.—*Average Amount of Feed, Digestible Protein, Digestible Nutrients, and Net Energy Consumed Daily by Heifers in Groups V and VI in Trial III during the Second Feeding Period, as Compared with Their Requirements*

Average Amount of Feed Consumed Per Heifer	Analyses		
	Digestible Protein *(pounds)*	Tot. Dig. Nutrients *(pounds)*	Therms Net Energy
GROUP V. SELF-FED GROUP (SECOND WINTER-FEEDING PERIOD)			
7.50 pounds corn silage contains	0.083	1.328	1.193
5.86 pounds alfalfa hay contains	0.621	3.024	2.004
13.36 pounds roughage contains	0.704	4.352	3.197
7.69 pounds cornmeal contains	0.546	6.283	6.767
6.51 pounds linseed oilmeal contains	1.992	5.071	5.794
2.66 pounds wheat bran contains	0.333	1.620	1.410
16.86 pounds grain contains	2.871	12.974	13.971
Total ration contains	3.575	17.326	17.168
Requirement of 830.3-pound heifer	1.329	10.296	
Amount fed in excess of requirement	2.246	7.030	
GROUP VI. HAND-FED GROUP (SECOND WINTER-FEEDING PERIOD)			
7.50 pounds corn silage contains	0.083	1.328	1.193
7.07 pounds alfalfa hay contains	0.749	3.648	2.418
14.57 pounds roughage contains	0.832	4.976	3.611
0.797 pounds cornmeal contains	0.057	0.651	0.701
0.597 pounds linseed oilmeal contains	0.183	0.465	0.531
1.195 pounds wheat bran contains	0.149	0.728	0.633
2.589 pounds grain contains	0.389	1.844	1.865
Total ration contains	1.221	6.821	5.471
Requirement of 581.25-pound heifer	1.104	8.603	
Amount fed in excess of requirement	0.117	—1.783	

their requirements. The heifers in Group V each consumed 6½ times as much grain per day as did those in Group VI, but not as much roughage, although they were given all they would eat. It can also be seen that the heifers in Group VI obtained 80.3 percent of their digestible proteins and 74.9 percent of their digestible nutrients from their grain ration, while those in Group VI obtained only 31.8 percent of their digestible protein and 27.0 percent of their digestible nutrients from their grain ration.

TABLE 8.—*Summary of First Feeding Trial (1921-22)*

Item	Group I (Self-fed)	Group II (Hand-fed)
WINTER PERIOD (158 DAYS)		
Number of heifers	4	4
Pounds gain in weight	298.8	205.0
Pounds gain per day	1.89	1.30
Pounds of grain per pound gain	7.29	3.83
Pounds of digestible protein per pound gain	1.61	1.19
Pounds of digestible nutrients per pound gain	4.65	5.28
Therms net energy per pound gain	7.56	6.19
Height at withers gained *(cm.)*	10.	10.
Pounds of grain per cm. gain in height	872.9	316.1
SUMMER PERIOD (203 DAYS)		
Pounds gain in weight	60.2	177.5
Pounds gain per day	0.30	0.87
Height at withers gained *(cm.)*	4.5	6.5
TOTAL PERIOD (361 DAYS)		
Pounds gain in weight	358.8	382.5
Pounds gain per day	0.99	1.06
Pounds of grain required per pound gain	6.07	2.06
Pounds of digestible protein per pound gain	1.34	0.64
Pounds of digestible nutrients per pound gain	6.68	3.84
Therms net energy per pound gain	6.37	3.32
Height at withers gained *(cm.)*	14.5	16.5

RESULTS OF FEEDING TRIALS

First Feeding Trial.—In Trial I, which started on November 25, 1921, the heifers were fed for a winter period of 158 days and then turned on pasture for 203 days. The results of these periods and the combined periods are given in Table 8 and in Figures 1 and 2.

It will be seen that during the 158-day winter period the 4 heifers in Group I, the self-fed group, gained an average of 298.8 pounds each in weight, while those in Group II, the hand-fed group, gained only 205 pounds in weight. The heifers in Group I made an average daily gain for this period of 1.89 pounds as compared to 1.30 pounds for those in Group II. The heifers in the self-fed group were in much better flesh at the end of this period than were the heifers in the hand-fed group. However, no difference was found in regard to skeleton growth as denoted by the height at withers.

It required 7.29 pounds of grain for each pound of gain with self-feeders as against 3.83 pounds with hand-fed heifers. The self-fed heifers consumed almost one-third more digestible protein per pound of gain than did the hand-fed group, but only slightly more digestible nutrients, or net energy, were required per pound of gain. This would indicate that heifers will gain in weight according to the

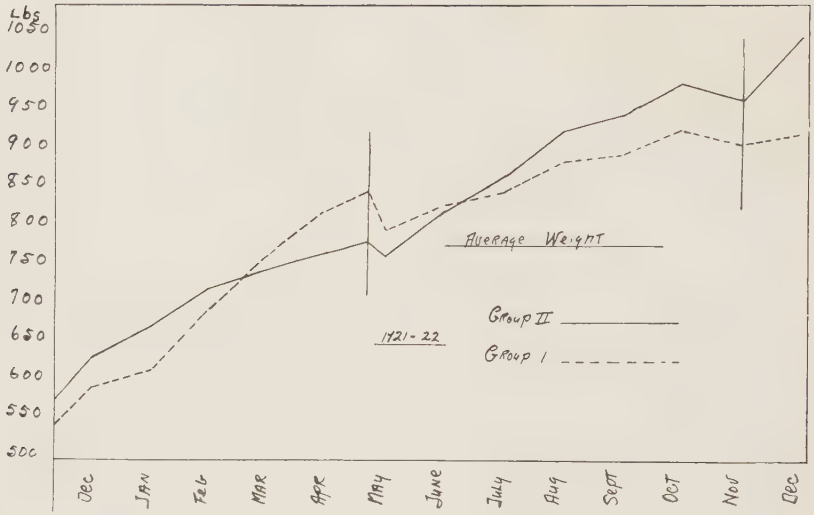


FIGURE 1.—Average Gains in Weight (pounds) of Group I (self-fed) and Group II (hand-fed) by Months (1921-22)

amount of digestible nutrients they receive, but this is not true in regard to skeleton growth.

During the following summer, when the heifers of both groups were turned together in a common pasture, the heifers in the self-fed group each gained an average of only 60.2 pounds in weight and 4.5 cm. in height, while the heifers in the hand-fed group each gained an average of 177.5 pounds in weight and 6.5 cm. in height. The self-fed group had found life easy during the winter months, and grazing offered little inducement to exertion, while the hand-fed heifers worked all the harder.

For the total period of 361 days the animals in the hand-fed group gained an average of 382.5 pounds in weight, while the animals

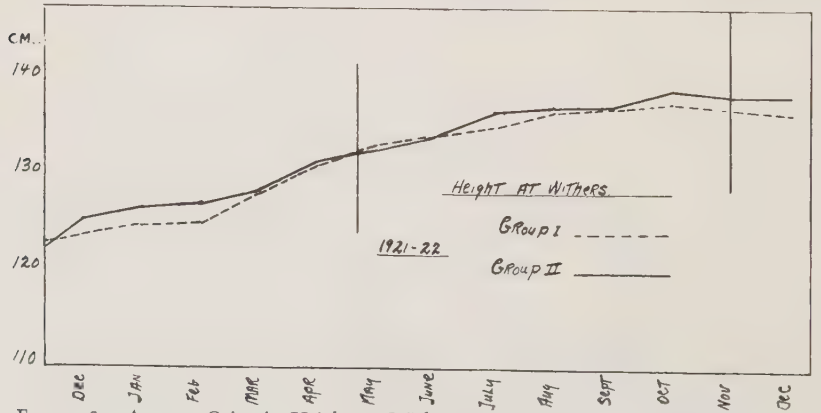


FIGURE 2.—Average Gains in Height at Withers (centimeters) of Group I (self-fed) and Group II (hand-fed) by Months (1921-22)

in the self-fed group gained an average of only 358.8 pounds. It required almost 3 times as much grain for one pound of gain in the self-fed group as in the hand-fed group. It also required about twice as much digestible protein, digestible nutrients, or net energy for one pound of gain, if no consideration is given to the food value of the pasture.

Second Feeding Trial.—In Trial II, which started on December 1, 1923, the heifers were fed for a winter period of 156 days and then turned on pasture for 194 days. The gains made by each group during these periods are given in Table 9 and in Figures 3 and 4.

TABLE 9.—*Summary of Second Feeding Trial (1922-23)*

Item	Group III (Self-fed)	Group IV (Hand-fed)
WINTER PERIOD (156 DAYS)		
Number of heifers	5	5
Pounds gain in weight	326.3	193.2
Average pounds gain per day	2.09	1.24
Pounds of grain per pound gain	7.2	3.1
Pounds of digestible protein per pound gain	1.59	0.80
Pounds of digestible nutrients per pound gain	6.38	6.69
Therms net energy per pound gain	6.30	6.21
Height at withers gained *(cm.)*	14.1	9.0
Pounds of grain per cm. gain in height	836.1	324.4
SUMMER PERIOD (194 DAYS)		
Average pounds gain in weight	165.9	218.3
Average pounds gain per day	0.83	1.13
Average height at withers gained *(cm.)*	4.3	8.4
TOTAL PERIOD (350 DAYS)		
Average pounds gain in weight	492.2	411.5
Average pounds gain per day	1.41	1.18
Pounds of grain required per pound gain	4.77	1.45
Pounds of digestible protein required per pound gain	1.05	0.38
Pounds of digestible nutrients required per pound gain	4.23	3.14
Therms net energy required per pound gain	4.17	2.92
Height at withers gained *(cm.)*	18.4	17.4

It will be seen that the five heifers in Group III, the self-fed group, during the winter months made an average gain of 326.3 pounds in weight, which is at the rate of 2.09 pounds per day, while those in Group IV, the hand-fed group, made an average gain of only 193.2 pounds, which is at the rate of 1.24 pounds gain per day. The heifers in Group III were in very much better condition at the end of this time than were those in Group IV.

During this period the heifers in Group III made a gain of 14.1 cm. in height at withers, while those in Group IV made a gain of only 9.0 cm.

It required 7.2 pounds of grain for each pound of gain made in Group III and only 3.1 pounds of grain for each pound of gain in Group IV. Group IV, however, made use of considerably more roughage than did Group III. The self-fed heifers consumed almost twice as much digestible protein to make a pound of gain as did the hand-fed heifers. However, the amount of digestible nutrients or net energy required for a pound of gain was not much different in the two methods of feeding.

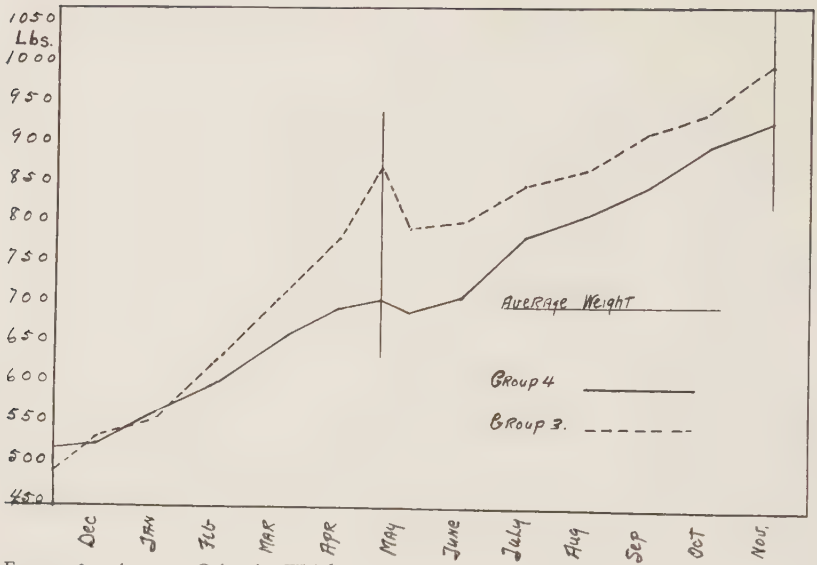


FIGURE 3.—Average Gains in Weight (pounds) of Group III (self-fed) and Group IV (hand-fed) by Months (1923-24)

During the following summer, when the heifers were turned into a common pasture (see Figs. 5 and 6), those in Group III, the self-fed group, gained an average of 165.9 pounds each in weight, while those in Group IV gained an average of 218.3 pounds in weight. During this period those in Group III gained at the rate of 0.83 pounds per day, while those in Group IV gained at the rate of 1.13 pounds per day. The heifers in Group IV also made much larger gains during

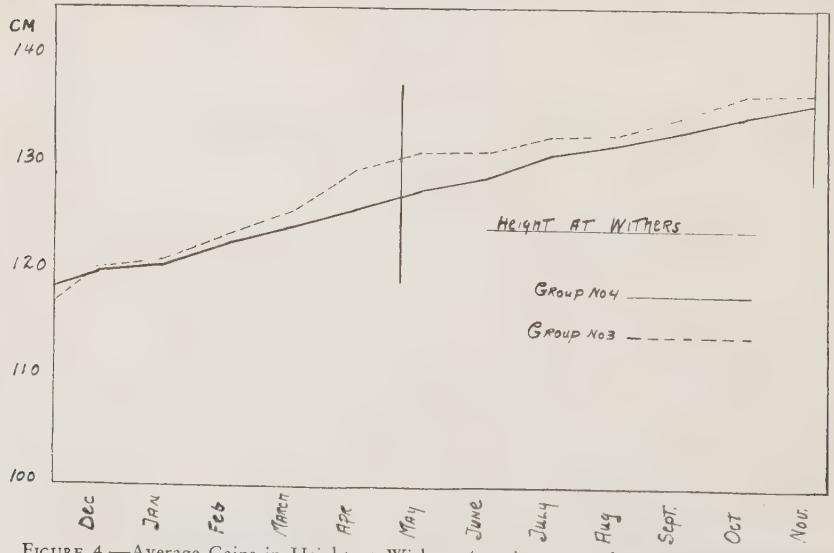


FIGURE 4.—Average Gains in Height at Withers (centimeters) of Group III (self-fed) and Group IV (hand-fed) by Months (1923-24)

FIGURE 5.—Group III (self-fed) as the animals appeared at time of turning on pasture in the spring

this period in skeleton growth, as denoted by the growth in height at withers. They gained an average of 8.4 cm. during this period as compared to 4.3 cm. for the self-fed group, Group III.

For the total period of 350 days the heifers in Group III made an average gain of 492.5 pounds each, while those in Group IV made a gain of 411.5 pounds. The heifers in Group III gained at the rate of 1.41 pounds per day, while those in Group IV gained at the rate of 1.18 pounds per day. For this entire period Group III consumed 4.77 pounds of grain for each pound of gain, while Group IV consumed 1.45 pounds of grain for each pound of gain. The heifers in Group III consumed almost 3 times as much protein as those in Group IV for each pound of gain and also considerably more digestible nutrients and net energy. No account, however, was taken of the amount of the various nutrients which were obtained from pasture.

Third Feeding Trial.—In Trial III, which started on December 21, 1923, the calves were fed for a winter period of 117 days and then turned out in a pasture together for a period of 198 days, after which they were returned to the stable for the second winter period. This period was 169 days in length. They were then turned out on pasture for a period of 198 days. The gains during the periods are shown in Table 10 and in Figures 7 and 8.

Table 10 shows that during the first winter period the calves in Group V made an average gain of 270.25 pounds each in weight, which was at the rate of 2.31 pounds per day. The calves in Group VI during the same period gained only 139 pounds in weight, which was at the rate of 1.19 pounds per day. During this period the calves in Group V gained 18.45 cm. in height, while those in Group VI gained only 12.25 cm.

FIGURE 6.—Group IV (hand-fed) as the animals appeared at time of turning on pasture in the spring

It required 4.64 pounds of grain to produce one pound in weight in Group V, the self-fed group, and only 2.07 pounds in Group VI, the hand-fed group. It required, however, very little more digestible nutrients or net energy for one pound gain in Group V than it did in Group VI.

During the following summer the calves in Group VI gained slightly more both in weight and in height than did those in Group V.

TABLE 10.—*Summary of Third Feeding Trial (1923-25)*

Item	Group V (Self-fed)	Group VI (Hand-fed)
FIRST WINTER PERIOD (117 DAYS)		
Number of heifers	4	4
Average pounds of gain in weight	270.25	139.0
Average pounds of gain per day	2.31	1.19
Pounds of grain per pound gain	4.64	2.07
Pounds of digestible protein per pound gain	1.36	0.88
Pounds of digestible nutrients per pound gain	4.65	5.28
Therms net energy	4.42	4.26
Height at withers gained *(cm.)*	18.45	12.25
Pounds of grain per cm. gain	272.03	93.71
FIRST SUMMER PERIOD (198 DAYS)		
Average pounds gain in weight	100.0	120.5
Average pounds gain per day	0.51	0.61
Average height at withers gained *(cm.)*	5.75	5.95
TOTAL PERIOD FIRST YEAR (315 DAYS)		
Average pounds gain in weight	370.25	259.5
Average pounds gain per day	1.18	0.82
Pounds of grain required per pound gain	3.39	1.10
Pounds of digestible protein required per pound gain	0.99	0.47
Pounds of digestible nutrients required per pound gain	3.40	2.83
Therms net energy required per pound gain	2.76	2.28
Height at withers gained *(cm.)*	24.2	18.2
SECOND WINTER PERIOD (169 DAYS)		
Average pounds gain in weight	370.6	72.5
Average pounds gain per day	2.19	0.43
Pounds of grain per pound gain	7.69	6.03
Pounds of digestible protein per pound gain	1.63	2.57
Pounds of digestible nutrients per pound gain	7.90	15.89
Therms net energy per pound gain	7.82	12.77
Height at withers gained *(cm.)*	13.2	5.4
Pounds of grain per cm. gain	863.6	324.0
SECOND SUMMER PERIOD (198 DAYS)		
Average pounds gain in weight	14.9	143.7
Average pounds gain per day	0.075	.726
Height at withers gained *(cm.)*	0.20	4.5
TOTAL PERIOD SECOND YEAR (367 DAYS)		
Average pounds gain in weight	385.5	216.2
Average pounds gain per day	1.05	0.59
Pounds of grain per pound gain	7.39	2.02
Pounds of digestible protein per pound gain	1.57	0.95
Pounds of digestible nutrients per pound gain	7.60	6.72
Therms net energy per pound gain	7.52	4.28
Height at withers gained *(cm.)*	13.4	9.9
TOTAL FOR BOTH YEARS (682 DAYS)		
Average pounds gain in weight	755.75	475.70
Average pounds gain per day	1.11	0.70
Pounds of grain per pound gain	5.43	1.52
Pounds of digestible protein per pound gain	1.21	0.69
Pounds of digestible nutrients per pound gain	5.54	3.96
Therms net energy per pound gain	5.41	3.19
Height at withers gained *(cm.)*	37.6	28.1

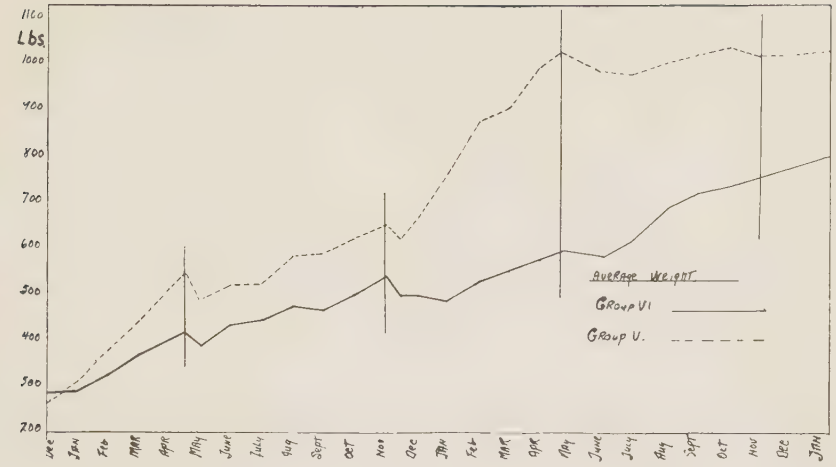


FIGURE 7.—Average Gains in Weight (pounds) of Group V (self-fed) and Group VI (hand-fed) by Months (1923-26)

However, they did not make as large gains as did the heifers in the other two trials. This was probably due to the fact that they were younger than the heifers in the previous groups and were not accustomed to consuming large quantities of pasture grass.

When the heifers were brought into the stable for the second feeding period those in Group V were noticeably larger than those in Group VI. During this second winter feeding period of 169 days the heifers in Group VI were fed a ration considerably below requirements as to digestible nutrients. As a result they made only small gains—an average of 72.5 pounds in weight and 5.4 cm. in height at withers. During the same period the heifers in Group V made a gain of 370.6 pounds each in weight and 13.2 cm. in height. They

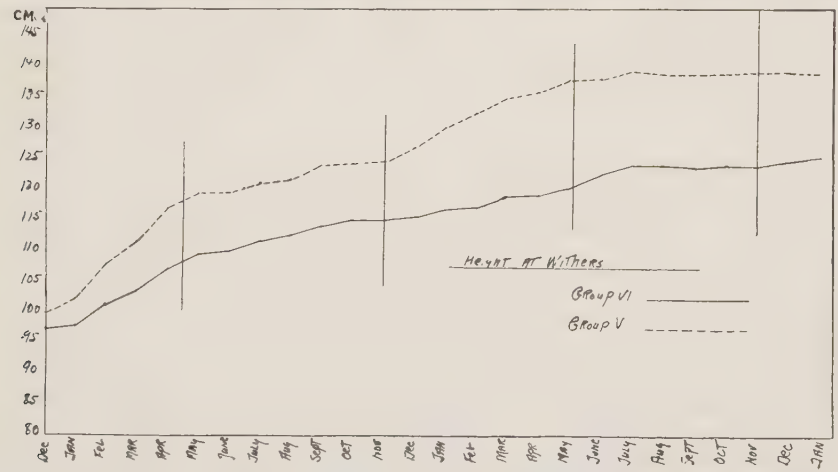


FIGURE 8.—Average Gains in Height at Withers (centimeters) of Group V (self-fed) and Group VI (hand-fed) by Months (1923-26)

made an average daily gain of 2.19 pounds, while the heifers in Group VI gained only 0.43 pounds per day.

To make these gains, however, it required in the case of Group V, the self-fed group, 7.69 pounds of grain for each pound of gain and only 6.03 pounds in the case of the heifers in Group VI. It required 2.57 pounds of digestible protein to produce a pound of gain in the case of the heifers in Group VI and only 1.63 pounds in the case of those in Group V. It also required 15.89 pounds of digestible nutrients, or 12.77 therms net energy, to make one pound of gain by the animals in Group VI as compared with 7.90 pounds of digestible nutrients or 7.82 therms net energy per pound of gain as made by the animals in Group V.

During the second summer the animals in Group V made practically no gain either in weight or in height at withers. The heifers had reached their full size during the period of heavy feeding. The heifers in Group VI, however, gained an average of 143.7 pounds each in weight and 4.5 cm. in height during the period. During this second year the heifers in Group V made a total gain of 385.5 pounds each in weight and 13.4 cm. in height at withers, while the heifers in Group VI were making a gain of only 216.2 pounds each in weight and 9.9 cm. in height at withers.

During the two years the heifers in Group V gained an average of 755.75 pounds each in weight and 37.6 cm. in height, while those in Group VI gained only 475.7 pounds each in weight and 28.1 cm. in height. The heifers in Group V, however, made only 15 percent of their increase in weight on pasture, while those in Group VI made 57 percent of their gain in weight on pasture.

Age of Freshening

One of the objects of the experiment was to determine if the heavily fed heifers would mature earlier than the hand-fed heifers so as to make a return at an earlier age and so compensate to a certain degree for the extra feed cost. Table 11, which gives data on the dates of freshening of the various heifers in the self-fed and hand-fed groups, indicates that there is very little difference in the age of the first calving between the two groups. While the self-fed groups, as is especially noticeable in Group V, seemed to reach full size at an earlier

TABLE 11.—*Ages of Freshening of Self-fed and Hand-fed Heifers*

Number of Heifer	Self-fed Groups — Age of Freshening			Number of Heifers	Hand-fed Groups — Age of Freshening		
	Yrs.	Mos.	Days		Yrs.	Mos.	Days
71	2	5	18	70	2	6	7
81	3	0	17	72	2	6	13
83	2	10	29	77	2	3	23
86	2	5	2	84	2	10	0
44	3	4	2	85	2	6	6
41	3	5	6	32	2	11	17
39	2	3	23	40	2	3	21
111	3	0	25	42	2	3	14
113	2	4	11	46	2	11	14
114	2	3	16	109	2	6	16
116	2	3	1	115	3	0	0
				141	2	8	24
Average	2	8	11	Average	2	7	16

TABLE 12.—*Production of Milk and Butterfat of Heifers in Each Group during First Lactation Period*

Self-fed Groups*			Hand-fed Groups†		
Number of Heifer	Pounds Milk	Pounds Fat	Number of Heifer	Pounds Milk	Pounds Fat
44	9,439	401	32	5,838	260
41	9,877	322	40	13,072	369
71	12,054	367	46	11,954	363
81	10,859	401	70	11,093	342
83	12,614	424	72	11,995	356
86	6,474	329	77	8,148	234
109	8,095	275	84	10,979	389
115	8,090	460	85	4,683	222
141	9,131	357	116	12,981	487
Average	9,626	371	Average	10,016	336

*2 Jerseys, 1 Ayrshire, 1 Guernsey, and 5 Holsteins.
†2 Guernseys and 7 Holsteins.

age than the hand-fed groups, yet the animals did not seem to come into milk at any earlier age. This may have been due to failure on the part of some of the heifers in the self-fed groups to conceive on account of heavy fleshing. Four heifers in these groups ran over 3 years of age before freshening, while only one in the hand-fed groups reached the age of 3 years.

Production

Table 12 gives the production of as many heifers as finished an entire lactation period in the herd. This table indicates that, when breed difference is taken into account, there is but little or no difference in the first calf production of the groups.

SUMMARY AND CONCLUSIONS

Three trials were conducted to compare the efficiency of wintering dairy heifers by the use of a self-feeder, with wintering them in the usual manner by hand-feeding. The first two trials were begun when the heifers were approximately one year old and were run during one winter feeding season and the following pasture season. In the third trial the animals were put on the self-feeder as soon as they were old enough to eat grain, and except when on pasture they were kept on the self-feeder until time of freshening.

The heifers fed by means of the self-feeder made much greater gains during the period when they were fed by means of the self-feeder than did the heifers fed by hand. However, when all of the heifers were turned in a common pasture, the self-fed heifers made much slower gains than did the hand-fed heifers. Greater gains made by the hand-fed heifers during the period when the heifers were kept on a common pasture tended to offset the gains made by the self-fed heifers during the winter months.

The self-fed heifers, especially those self-fed from birth, reached their full size at an earlier age than did those fed by hand. The heifers fed by hand made up for their slow growth during the winter months by making greater growth during the summer months when they were on pasture and by continuing to grow for a longer period of time.

The self-fed heifers consumed less roughage but much more grain per pound of gain (approximately 4 times as much) as did those fed by hand. During the second year of Trial III, the self-fed

heifers obtained 80.3 percent of their digestible protein and 74.9 percent of their digestible nutrients from the grain ration, while the hand-fed heifers obtained only 31.8 percent of their digestible protein and 27 percent of their digestible nutrients from their grain ration.

The amount of digestible protein consumed for one pound of gain was very much greater (more than 100 percent on the average) for the self-fed heifers than for the hand-fed heifers. This was true when the amount of protein which they obtained from the pasture was not considered. It was not true, however, when the heifers were being fed less than their requirements of total nutrients, which occurred during the second winter in the case of Group VI.

The amount of total digestible nutrients consumed per pound of gain was higher on the average (about 50 percent) for the self-fed heifers if no account is taken of the amount obtained from the pasture. However, when the heifers were on winter feed there was very little difference in the amount of total digestible nutrients consumed per pound of gain. During the third trial, when the hand-fed group was being fed less than its requirements, it required considerably more for a pound gain than in the case of the self-fed group. This would indicate that a heifer to be most efficient should be fed somewhere near her requirements as denoted by the Morrison Feeding Standard.

The hand-fed groups made most of their gain when on pasture, while the self-fed groups made most of their gains during winter feeding. In the case of Group V, the self-fed group, only 15 percent of the gain was made on pasture, while Group VI, the hand-fed group, made 57 percent of their total gain on pasture.

Dairy heifers can make proper selection of grains as far as health and digestion is concerned, but not as to the proper or economical food value. The self-fed heifers did not come into milk at any earlier age, nor did they possess any better dairy qualities than did those fed by hand.

In conclusion it can be said that the self-feeding of grain is an expensive method of raising dairy heifers, as they make their growth at the expense of large quantities of expensive grains and small quantities of roughages and pasture, as compared to heifers fed by hand.

LITERATURE CITED

1. Arnett, C. N.
   1921. THE SELF-FEEDER FOR DAIRY CALVES. Montana Exp. Sta. Rept. 38:35.
2. Hunt, R. E.
   1918. SELF-FEEDERS FOR DAIRY COWS. Va. Exp. Sta. Rept., p. 50.
3. McCandlish, A. C.
   1923. THE USE OF THE SELF-FEEDER FOR YOUNG DAIRY CALVES. Jour. Dairy Sci. 6:500.
4. ———
   1923. RAISING DAIRY HEIFERS BY MEANS OF THE SELF-FEEDER. Jour. Dairy Sci. 6:572.
5. ———
   1924. SELF-FEEDING A GRAIN MIXTURE TO YOUNG CALVES. Jour. Dairy Sci. 7:160.
6. Nevens, W. B.
   1919. THE SELF-FEEDER FOR DAIRY CALVES. Jour. Dairy Sci. 2:435.
7. ———
   1927. EXPERIMENTS IN THE SELF-FEEDING OF DAIRY COWS. Ill. Exp. Sta. Bul. 289.
8. Olson, T. M.
   1927. SELF-FEEDERS NOT GOOD FOR CALVES. The Jersey Bulletin, 46:324.
9. Tretsven, J. O.
   1922. SELF-FEEDERS FOR GROWING DAIRY CALVES. Hoard's Dairyman, 63:723.

Bulletin 233 April, 1930

The Relationship between the Number and Weight of Eggs and Body Weight of Leghorn Fowls during the First Three Years of Production

by HORACE ATWOOD and T. B. CLARK

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

AGRICULTURAL EXPERIMENT STATION STAFF

JOHN R. TURNER, Ph. D., LL. D. ..... President of the University
F. D. FROMME, Ph. D. ..... Dean and Director
GERALD JENNY, M. S. ..... Agricultural Editor
JOHN C. JOHNSTON ..... Chief Clerk

AGRONOMY AND GENETICS

R. J. Garber, Ph. D.
Agronomist and Geneticist
E. P. Deatrick, Ph. D.
Associate Agronomist
W. H. Pierre, Ph. D.
Associate Agronomist
T. C. McIlvaine, Ph. D.†
Assistant Agronomist
D. R. Dodd, B. S.,‡
Assistant Agronomist
M. M. Hoover, M. S.
Assistant Agronomist
H. K. Rowley, M. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, D. Sc.
Animal Husbandman
Chas. V. Wilson, M. S.
Assistant Animal Husbandman
J. H. Longwell, M. A.
Assistant Animal Husbandman
J. H. Rietz, D. V. M.
Associate Veterinarian
R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman
R. S. Glasscock, M. S.**
Assistant in Veterinary Science

CHEMISTRY

R. B. Dustman, Ph. D.
Agricultural Chemist
Chas. E. Weakley, Jr., B. A.
Assistant Chemist
L. P. Hansen, Ph. D.
Assistant Chemist
T. B. Leith, M. S.**
Assistant Chemist
Leland Shriver, M. S. Ch. E.
Assistant in Agricultural Chemistry

DAIRY HUSBANDRY

H. O. Henderson, Ph. D.
Dairy Husbandman
L. M. Thurston, Ph. D.
Assistant Dairy Husbandman
K. S. Morrow, M. S.
Assistant Dairy Husbandman
L. F. Sutton, B. S. Agr.††
Assistant Dairy Husbandman
R. A. Ackerman, B. S.
Assistant in Dairy Husbandry

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist
W. E. Rumsey, B. S.**
State Entomologist
Edwin Gould, B. S. Agr.
Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist
F. D. Cornell, Jr., M. S.
Assistant Farm Mechanician
W. W. Armentrout, M. S.
Assistant Farm Economist
R. O. Stelzer, B. S.
Assistant in Farm Economics

HOME ECONOMICS

Rachel H. Colwell, M. A.
Home Economist
Hazel C. Cameron, M. A.
Research Specialist in Nutrition

HORTICULTURE

H. E. Knowlton, Ph. D.
Horticulturist
K. C. Westover, M. S. Agr.
Assistant Horticulturist
F. W. Craig, M. S. Agr.**
Assistant Horticulturist
M. B. Hoffman, M. S.
Assistant in Horticulture
E. N. McCubbin, M. A.
Assistant in Horticulture
A. P. Dye, M. S. Agr.
Assistant in Horticulture

PLANT PATHOLOGY

C. R. Orton, Ph. D.
Plant Pathologist
Anthony Berg, M. S.
Associate Plant Pathologist
L. H. Leonian, Ph. D.
Associate Plant Pathologist
F. J. Schneiderhan, M. S.
Associate Plant Pathologist
E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr.
Poultry Husbandman
T. B. Clark, B. S. Agr.
Assistant in Poultry Husbandry

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-Station, Lakin, W. Va.
‡Resigned, February, 1930.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
††In charge of the Reymann Memorial Farms, Wardensville, W. Va.

*The Relationship between the Number and Weight of Eggs and Body Weight of Leghorn Fowls during the First Three Years of Production**

by HORACE ATWOOD and T. B. CLARK

THE INCREASING importance of the poultry industry demands more definite knowledge than is now available concerning the normal variation in the fecundity of fowls at different ages and the changes taking place in the weight of the eggs and in the weight of the fowls from year to year. This bulletin is intended as a contribution on this subject, and in addition there is considered (1) the number and weight of the eggs laid by a bird as influenced by the weight of the bird; (2) the relationship between the number of eggs laid by a bird and the weight of the eggs; (3) the relationship between early sexual maturity and the fecundity of the birds at different ages.

In discussing the results of this investigation it has been the endeavor of the authors to interpret the findings so as to afford new viewpoints from which future progress may be made.†

CONDITIONS OF THE EXPERIMENT

The present experiment was begun in 1925 with 200 Single-Comb White Leghorn pullets. The results for the first year have been discussed in Bulletin 220 of this Station in which it is reported that fowls were fed a uniform ration from year to year. Each bird was weighed once each month. They were trapped and the weight of each egg was recorded to one-tenth gram. At the end of the first year the birds were transferred from the small colony houses in which the work was begun to a Missouri type laying house.

Mortality and Health of Fowls

During the first year 12 birds died, 10 being killed by dogs and two through disease. During the second year there were 10 mortalities and during the third year, 13. An infestation of worms occurred during the latter year. To remedy this an effective vermifuge was administered. The infestation and subsequent treatment probably increased the mortality and reduced production somewhat for the year, but at no time was there an outbreak of an infectious disease.

*Submitted for publication September, 1929.

†Use has been made of more than 72,000 numbers showing egg weights and more than 6,000 numbers showing body weights, as the basis of the report in this bulletin.

RESULTS OF THE EXPERIMENT

The following discussion of results is based on the records made by 178 birds during the first and second years and by 165 birds which remained in the experiment at the end of the third year.

Annual Egg Production as Influenced by Age of Birds

Egg Production for First Two Years. The influence of senescence on egg production has received considerable attention from poultry investigators. Jull *(1928)* has summarized the results of 25 experiments in which data are presented showing the number of eggs laid by various breeds during the first two years of production. In these experiments there were 3,979 birds consisting of 540 Barred Plymouth Rocks, 811 Rhode Island Reds, 230 Wyandottes, and 2,398 Leghorns. If the results of two of the experiments, in which the egg production for the second year of 87 fowls appears to be greater than for the first year, be disregarded, then the unweighted average egg production for the first year is 195.09, and for the second year 140.08, or a decrease due to senescence of 26.1 percent. It was observed that the higher the production the first year, the greater the decrease the second year, and that the average decrease in the production of the general purpose breeds for the second year was somewhat greater than in the case of the Leghorns.

Egg Production for First Three Years. Ball, Alder, and Egbert *(1916)* found the following average production of eggs for the first 3 years of selected flocks whose records were available:

Type of Fowl	*Egg Production*		
	Year: First	*Second*	*Third*
Leghorns	180	146	119
General purpose breeds	177	116	93
Decrease in production of Leghorns *(percent)*		19	18
Decrease in production of general purpose breeds *(percent)*		34	20

It may be observed that the decrease in egg production from the first to the second year as given by Ball, Alder, and Egbert is in reasonably close agreement with the figures as given by Jull when consideration is given to the fact that Jull's summary is based on flocks of which 60 percent were Leghorns and 40 percent general purpose breeds.

Influence of Senescence

The mean egg production of the White Leghorns in the present experiment during the first 3 years of the test was as follows:

	Year of Test		
	First	*Second*	*Third*
Eggs laid	170.219±2.039	135.978±1.875	106.151±1.891
Decrease		34.241±2.770	29.827±2.663
Decrease *(percent)*		20	22

These results agree closely with the results for Leghorns as summarized by Ball, Alder, and Egbert. It may be concluded that under usual commercial conditions the decrease in egg production with Leghorns will be about 20 percent per year.

Decrease Due to Senescence Found Uniform from Year to Year. Brody, Henderson, and Kempster *(1924)* have shown that the decline in egg production with age is a fairly constant percentage of the preceding year's production. These authors suggest that it is not the number of oocytes in the hen that limits production but rather the decline in vigor of some limiting organ or organs, and that this decline in vigor follows the course of a simple chemical reaction.

Factors Affecting Weight of Eggs

Little systematic work has been done by poultry investigators to determine the amount of fluctuations or the various causes which bring about such fluctuations in the weight of the eggs of the domestic fowl. It is well known that in some breeds of poultry certain individuals lay larger eggs than others, and that pullet eggs gradually increase in size as the birds grow older. The senior author has shown *(1926)* that an unbalanced ration fed to laying hens may decrease the egg weight by as much as 12 percent. He has also shown *(1923)* that if chicks are fed during the early stages of their growth so that they are permanently stunted, then the eggs which they may lay later will be smaller than if the birds had been fed a ration permitting them to attain a normal size. It is also known *(1923)* that there is a seasonal variation in the weight of eggs, the eggs being smaller in summer and heavier in fall and winter. The senior author has also shown *(1917)* that the first eggs of a cycle are usually heavier than the eggs laid later in the same cycle. From these considerations it is evident that the weight of an egg at any particular time is the resultant of various hereditary and environmental factors.

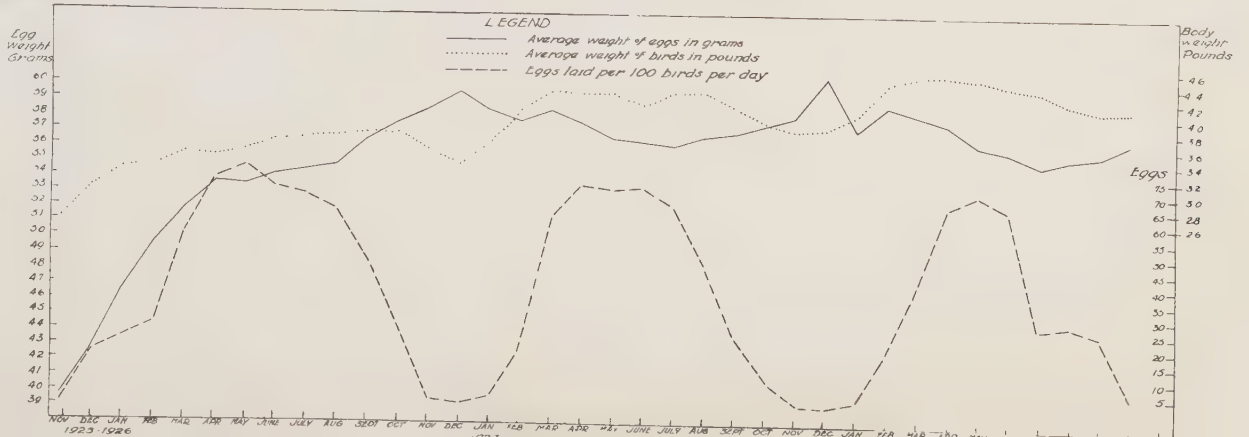
Changes in Egg Weight Due to Senescence. Table 1 shows the average weight of the eggs laid during each month of the 3 years, the total weight of the eggs for each month, the average weight of the eggs for each year, and the weight of the eggs laid per bird per year. This table shows that the average weight of the eggs laid during the first or pullet year was 53.24±.16 grams, and that the weight for the second year was 56.87±.17 grams, an increase of 3.63±.23 grams, or 6.8 percent. There was no significant change from the second to the third year in the average weight of the eggs, showing that in this case the normal weight of the eggs for the mature fowls was arrived at during the second year of production.

The weight of the eggs produced per bird during the first year was 9,029 grams and for the second year 7,726 grams, a decrease, due largely to senescence, of 1,303 grams, or 14.4 percent. The decrease for the third year as compared with the second was 1,718 grams, or 22.2 percent. It is evident therefore that the decrease in total egg substance due to advancing age accompanies decrease in egg number.

TABLE 1.—*Average and Total Weight of Eggs Produced during the Three Years of Test (1925-28), by Months*

Month	First Year		Second Year		Third Year	
	Average Weight of Eggs in Grams	Total Weight of Eggs in Grams (178 Birds)	Average Weight of Eggs in Grams	Total Weight of Eggs in Grams (178 Birds)	Average Weight of Eggs in Grams	Total Weight of Eggs in Grams (165 Birds)
November	39.4	2,681	58.1	8,362	57.9	7,768
December	42.7	46,388	59.6	2,684	60.4	483
January	46.5	60,459	58.3	10,908	56.9	10,418
February	49.6	64,349	57.6	55,475	58.6	52,864
March	51.9	163,137	58.2	197,151	58.0	123,638
April	53.5	212,700	57.6	222,393	57.4	186,825
May	53.3	227,953	56.5	221,204	56.2	198,879
June	54.0	207,318	56.2	213,301	55.8	178,945
July	54.1	203,154	55.8	201,487	54.9	77,427
August	54.4	192,062	56.5	144,295	55.3	80,811
September	56.1	143,982	56.6	69,734	55.5	57,328
October	57.3	83,000	57.1	28,196	56.4	15,915
Total		1,607,183		1,375,190		991,301
Average	53.24 ± .16	9,029	56.87 ± .17	7,726	56.50 ± .18	6,008

FIGURE 1.—Rate of egg production, mean weight of birds, and mean weight of eggs for each month of the three years of the experiment.


LEGEND
Average weight of eggs in grams
Average weight of birds in pounds
Eggs laid per 100 birds per day
Egg Weight Grams
Body Weight Pounds
Eggs
NOV DEC JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV DEC JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV DEC JAN FEB MAR
1925-1926

Seasonal Variation in Egg Weight. Table 1 also shows that during the first year of the trial the weight of the eggs increased with considerable regularity from the minimum of 39.4 grams in November to the maximum of 57.3 grams during the following October. This increase in egg weight during the pullet year, paralleling the increase in body weight, is entirely dissimilar to the distribution of egg weight during the two following years. During these two later years the minimum egg weight occurs in the hot summer months, and the maximum weight during late fall or at the beginning of winter, when egg production is at low ebb.

This distribution of egg weight agrees with earlier findings of the senior author *(1923)*, who found that in general, and especially after the pullet year, the greater the number of eggs laid during a month, the smaller they tend to become during that month. Experiments by Hadley *(1919)*, whose results were based primarily on the pullet year, seemed to indicate that increased production is accompanied by increased mean weight of the eggs. Undoubtedly this situation may arise when the increased production is brought about by changing to a better ration, or when it is accompanied by an increase in the mean weight of the birds as during the pullet year. The evidence on hand, however, shows that with a uniform ration and with mature fowls, increased production is usually accompanied by a decreased mean egg weight.

If the tendency toward decreased egg weight, which is brought about by increased production, could be overcome by more skillful feeding or otherwise, it might result in maintaining egg production for a longer time at a high level. Decreased egg weight under these circumstances may indicate that the ration may not supply sufficient digestible nutrients or may not be sufficiently concentrated for the use of the birds under the conditions of maximum production.

Seasonal Influence on Egg Production

Table 2 shows the total number of eggs and the rate of production for each month of the 3 years.

The minimum rate of production for the pullets occurred in November, when they first began to lay, and the maximum rate in May, when they laid at the rate of 78.6 eggs per day per 100 birds. From this peak, production decreased gradually until the end of the first laying year. During the two following years the minimum rate of production was in December, while the heaviest production occurred in April for the second year and in May for the third year.

During all 3 years the heaviest production occurred during the months of April, May, and June. The rate of production during these months did not vary much during any year. The minimum production was during November, December, and January and it seems entirely probable that, in any effort to increase the production of the birds in West Virginia, the conditions affecting egg production during these 3 months should receive first attention. Under commercial

TABLE 2.—*Number of Eggs Produced and Rate of Laying during the Three Years of Test, by Months*

Month	First Year		Second Year		Third Year	
	Eggs per Month (178 Birds)	Eggs per 100 Birds per Day	Eggs per Month (178 Birds)	Eggs per 100 Birds per Day	Eggs per Month (165 Birds)	Eggs per 100 Birds per Day
November	68	1.27	144	2.70	134	2.71
December	1086	19.68	45	.82	8	.16
January	1301	23.58	187	3.39	183	3.57
February	1298	26.04	963	18.66	901	18.83
March	3145	57.00	3389	61.42	2131	41.66
April	3977	74.48	3864	72.36	3250	65.66
May	4275	78.60	3916	70.97	3535	69.11
June	3842	71.95	3793	71.03	3205	64.74
July	3758	68.14	3608	65.39	1410	27.57
August	3532	64.01	2552	46.25	1460	28.54
September	2565	48.03	1232	23.07	1032	20.85
October	1449	26.26	494	8.95	282	5.51
Total	30,296		24,187		17,531	
Average	170.2 per year	46.63	135.9 per year	37.23	106.2 per year	29.03

conditions reliance is now placed on pullets to supply eggs during this period of low production, but it should be possible to shorten considerably this period by breeding for a shorter moult, or perhaps by feeding a more concentrated or more stimulating ration.

Body Weight

Table 3 shows the mean body weights of the birds for each month of the 3 years. This table shows that during the pullet year the weight of the birds increased with a fair degree of regularity from the beginning of the year to its close. The most rapid gain in weight was during the month of November, with an increase of almost one-half pound per bird. The monthly changes in weight were small, but the tendency to become heavier with increasing age is apparent.

TABLE 3.—*Average Body Weight of Birds for the Three Years by Months*

Month	First Year	Second Year	Third Year
	(pounds)	*(pounds)*	*(pounds)*
November	2.62	3.58	3.80
December	3.10	3.37	3.82
January	3.32	3.62	4.01
February	3.37	4.02	4.41
March	3.50	4.27	4.56
April	3.46	4.23	4.57
May	3.56	4.22	4.49
June	3.67	4.12	4.40
July	3.69	4.25	4.35
August	3.70	4.27	4.19
September	3.78	4.11	4.14
October	3.76	3.82	4.16
Average	3.46±.01	3.99±.02	4.25±.02

During the second year the minimum weight was noted on the first of December. A fairly uniform increase in weight followed until the first of March, when the weight declined slightly until the first of June. The average weight for the second year was slightly more than one-half pound greater than during the pullet year, or an increase of 15.3 percent.

During the third year the birds were lightest in weight on the first of November and heaviest in March and April. The mean weight of the birds was about one-fourth pound greater than during the second year. After the pullet year there was a strong tendency for the weight to decrease during October, November, and December, or during the period of lowest egg production. It seems possible that if the live weight could be maintained at a higher level during those months it might have a beneficial effect on the egg production at that time.*

The rate of egg production, the mean weight of the birds, and the mean weight of the eggs for each month of the 3 years are shown in Figure 1 on page 6.

Standard Deviations and Yearly Correlations in Egg Production

The mean egg production per bird for each of the 3 years and the standard deviation in the number of eggs are shown in the following schedule:

	Egg Production	*Standard Deviation*
First year	170.219±2.039	40.326±1.442
Second year	135.978±1.875	37.076±1.325
Third year	106.151±1.891	35.988±1.336

The correlations based on the production of the 165 birds remaining at the end of the third year are the following:

Correlation between production of first and second years: r = +.473±.041
Correlation between production of first and third years: r = +.357±.046
Correlation between production of second and third years: r = +.561±.035

The mean egg production as influenced by the age of the birds has been discussed in this publication. The standard deviation in the number of eggs laid was somewhat less in the case of the older fowls. This agrees with earlier findings of the senior author *(1926)*. During all 3 years the deviation was high, indicating a high degree of variability in the population.

The correlation in the egg production from one year to another was significant in all cases, showing that on the average a reasonably good layer the first year would probably be a reasonably good layer during the second and third years. This relationship, however, is not marked, showing that with a particular bird various other factors besides heredity are involved in determining the number of eggs laid from year to year.

*This matter should be investigated further.

Standard Deviations and Yearly Correlations in Egg Weight

The mean weight of the eggs for each year and the standard deviations in the weight for the 3 years are shown in the following schedule. The constants for the first two years are based on the production of the 178 birds remaining in the test at the end of the second year, and for the third year on the production of the 165 birds remaining at the end of that year.

	Mean Egg Weight	*Standard Deviation*
First year	53.244±.166 grams	3.276±.117
Second year	56.876±.171 grams	3.386±.121
Third year	56.506±.180 grams	3.438±.128

The correlations of the mean egg weights for each bird for the different years were found to be as follows:

Correlation in mean egg weight between first and second years: ---------- r = +.861±.013

Correlation in mean egg weight between second and third years: ---------- r = +.903±.010

This is a high degree of correlation and shows that the characteristic egg weight for a bird is a relatively stable character, persisting from year to year. The uniformity in the standard deviation for the 3 years indicates that there was no change in variability in the weight of the eggs due to senescence or other factors.

Standard Deviations and Yearly Correlations in Body Weight

The mean weight of the birds for each year, the standard deviation in weight, and the coefficient of variation for the three-year period are shown below:

	Mean Body Weight	*Standard Deviation*	*Coefficient of Variation*
First year	3.465±.014 pounds	.227±.010	6.55±.45
Second year	3.996±.019 pounds	.374±.013	9.35±.78
Third year	4.256±.022 pounds	.429±.016	10.08±.92

The correlation between the body weights for the first and second years was: r = +.827±.016, and for the second and third years: r = +.918 ±.008. These coefficients show a high degree of continuity in the relative body weights from year to year.

The coefficients of variation, which became larger as the birds became older, indicate a greater variability in the weight of the birds with increasing age. This may be because the poorer layers take on more weight with increasing age than is the case with the better layers.

To test this suggestion the coefficients of correlation were calculated between the increase in the body weight from the first to the third year and (1) the egg production for the first year; (2) the production for the third year; and (3) the decrease in the production from the first to the third year. The results are shown below: *(Cf. Tables 2 and 3.)*

Characters Compared (165 Birds)	*Constants*
Increase in mean body weight for the third year as compared with the first year, and egg production during the first year	$r = -.086 \pm .052$
Do. and egg production during third year	$r = -.129 \pm .051$
Do. and decrease in eggs laid during third year as compared with first year	$r = +.033 \pm .052$
Mean increase in weight from first to third year	$0.787 \pm .014$ pounds
Standard deviation of increase in weight	$0.258 \pm .010$
Mean decrease in number of eggs from first to third year	63.75 ± 2.30
Standard deviation of decrease in egg production	43.98 ± 1.63

The evidence shows that there is no connection between changes in body weight and egg production. A bird which has taken on extra weight during the third year is as likely to be a good layer as one that has remained lighter in weight.

Correlations Between Body Weight and Egg Weight

In 1925 the senior author observed that the heavier birds of a flock usually lay the heavier eggs. The present investigation confirms the earlier findings. The correlations between mean body weight and mean egg weight for the 3 years are as follows:

Egg weight for first year and body weight for that year:	$r = +.458 \pm .040$
Egg weight for second year and body weight for that year:	$r = +.434 \pm .040$
Egg weight for third year and body weight for that year:	$r = +.426 \pm .043$

These coefficients are all positive and significant and indicate that the heavier birds lay the heavier eggs.

Working with 40 Barred Plymouth Rock pullets Jull *(1924)* found a positive correlation of $.344 \pm .094$ between maximum body weight and mean egg weight for the year. This coefficient is in fairly close agreement with those reported above.

TABLE 4.—*Average Egg Weight under Various Body Weights of Birds in Canadian Egg-Laying Contests*

Body weight *(Pounds)*	Under 3	3- 3½	3½- 3¾	3¾- 4	4- 4½	Over 4
Average egg weight *(Ounces per dozen)*	23.0	23.3	23.7	23.9	24.4	24.9

In the Report of the Sixth, Seventh, and Eighth Annual Canadian National Egg-Laying Contests *(1929)* the relationship between body weight and egg weight is considered, basing the conclusions on data obtained from 1,772 White Leghorns and 1,947 birds of the heavier breeds. Table 4 shows the relationship between body weight and egg weight for White Leghorn pullets in the Canadian contests.

There is a gradual increase in egg size as the body weight increases. All evidence confirms the results of the present investigation and also that of the earlier work done at this Station.

During the first year of the present investigation there was a progressive increase in the weight of the birds and also a similar increase in the weight of the eggs from month to month. The coefficient of correlation between the monthly weight of the birds and the monthly weight of the eggs was found to be $+.996 \pm .013$.

Regulation of Egg Weight by Culling Undersized Pullets. The mean egg weight for the birds in the present investigation for the pullet year was found to be 53.2 grams, or 22½ ounces per dozen,—too low to meet the requirements for standard-size eggs. The question arises as to how the egg size could be increased quickly. From the evidence presented with reference to the relationship between body weight and egg weight it would seem that by rigid selection of the large, well-developed pullets the average egg size could be materially increased.

TABLE 5.—*Percentage of Pullets of Different Body Weights in Each Class of Egg Weights, and Mean Weight of Eggs Laid by the Pullets in Each Class*

Body Weight in Pounds on Nov. 1, 1925	Number of Birds	Percentage of Pullets in Each Class / Average Weight of Eggs in Grams during April, 1926				Mean Weight of Eggs (grams)
		44 to 48 grams	49 to 53 grams	54 to 58 grams	59 to 63 grams	
		(percent)	(percent)	(percent)	(percent)	
2.0 to 2.4	43	16.28	53.49	23.25	6.98	51.8
2.5 to 2.9	127	2.36	47.24	44.88	5.51	53.9
3.0 to 3.4	14		35.71	64.28		54.9

As indicated in Table 5, the pullets in the present experiment on November 1 of the pullet year were divided into three classes according to body weight. The table shows the mean weight of the eggs laid by the birds in the three classes and the percentage distribution of these eggs arranged in classes according to weight.

If the birds in the first class had been removed, constituting about 25 percent of the flock, virtually all of the birds laying eggs less than 22 ounces in weight per dozen would have been eliminated. Table 5 also shows that the large birds, those in the third class, laid eggs averaging slightly more than 3 grams heavier than the eggs laid by the birds in the first class.

From the above it is evident that through the removal of the smaller pullets in the fall an appreciable increase can be attained in the average weight of the eggs laid by the flock.

Correlation Between Number and Mean Weight of Eggs

It is generally assumed that the heavy layers of a flock have a tendency to lay eggs slightly smaller than the average for that strain. If this is so, it might be possible in breeding for increased production to produce birds that would lay more eggs, but if these eggs are smaller there might be no improvement in the birds as producers of egg substance. Hence it is important to know whether there is any connection between the number of eggs that a hen may lay and the weight of these eggs.

In 1923 the senior author reported correlations between the number of eggs laid and their mean weight as follows:

Flock	*Number of Birds*	*Correlations*
A—pullets	24	$r=+.41\pm.11$
B—pullets	24	$r=+.26\pm.13$
C—pullets	20	$r=+.19\pm.14$
D—pullets	20	$r=+.22\pm.14$
A—yearlings	23	$r=+.24\pm.13$
B—yearlings	21	$r=+.03\pm.15$

None of these coefficients is significant, with possibly an exception in the case of Flock A pullets. During the second year of production in this flock the coefficient is not significant.

Jull *(1924)* in reporting data from 40 pullets found no significant correlation between egg weight and production.

Parkhurst *(1925)* in reporting data from 41 Leghorn pullets found that the coefficient of correlation between 365-day production and the mean weight of the eggs for the same period was: $r=-.1541\pm.1028$, which is not significant.

In 1925 the senior author reported correlations between the number of eggs laid by a bird in one year and the mean weight of the eggs as follows:

Flock	*Year of Production*	*Correlations*
ACE	First	$r=-.225\pm.068$
BDF	First	$r=+.177\pm.069$
AC	Second	$r=+.260\pm.097$
BD	Second	$r=-.021\pm.107$
A	Third	$r=+.015\pm.140$
B	Third	$r=-.287\pm.135$

In this case three of the coefficients were positive and three negative. None, with the exception of Flock ACE for the first year, is significant.

In the present investigation the following results have been obtained:

Year	*Number of Birds*	*Coefficient of Correlation*
1	178	$r=+.180\pm.049$
2	178	$r=+.052\pm.050$
3	165	$r=+.044\pm.052$

None of these coefficients is significant. The evidence at hand shows that there is no connection between the fecundity of a bird and the size of her eggs. Stated in other words, a heavy layer is as likely to lay large eggs as small ones.

Correlation between the Number of Eggs and Mean Weight of Birds

Considerable work has been done by poultry investigators to determine the relationship between the weight of the body and the fecundity of fowls. Lewis, Hannas, and Wene *(1919)* studied the relationship between body weight and egg production with 556 Leg-

horns in the Vineland Egg-Laying Competition. The coefficient of correlation as computed by Platt *(1927)* was +.0734±.0285. Sherwood *(1922)*, using data from 128 Leghorns, reported a coefficient of correlation between the annual production and the body weight of the birds at the end of the laying year, of +.009±.060. Hervey and Lewis *(1921)*, working with 80 Barred Rocks, found a positive correlation between body weight and egg production of .1269±.0742. Jull in the same year with 40 Barred Rocks reported a negative correlation of —.114±.093 between the maximum body weight of the birds and the annual production. Platt *(1927)*, using the data derived from the records of 435 Leghorns in the First International Egg-Laying Contest at Vineland, N. J., found the coefficient of correlation for the pullet year to be —.0630±.0322, and for the yearling year, —.3314±.0293.

The experiments referred to above indicate little if any connection between the weight of a bird and the number of eggs that she may lay, although Platt *(1927)* drew the conclusion that White Leghorn pullets should attain a body weight of approximately 4 pounds before the winter of their first laying year, and that a body weight in excess of 4½ pounds during their yearling year would be detrimental to egg production.

TABLE 6.—*Relationship Between Body Weight and Number of Eggs Laid by White Leghorns in Canadian Egg-Laying Contests*

Body Weight	Number of Birds	Average Egg Production
Under 3 lbs.	96	137.9
3 lbs. to 3.5 lbs.	314	158.6
3.5 lbs. to 3.75 lbs.	378	179.1
3.75 lbs. to 4 lbs.	425	192.0
4 lbs. to 4.5 lbs.	376	200.9
4.5 lbs. and above	183	206.6

In the Report of the Sixth, Seventh, and Eighth Annual Canadian National Egg-Laying Contests *(1929)* a comparison is made between the body weights and the egg production of 1,772 White Leghorns. A summary of the data is given in Table 6. This table shows a very decided correlation between the weight of the White Leghorns in these contests and the average number of eggs laid. The relationship was slightly less marked in the case of the Barred Rocks, White Wyandottes, and Rhode Island Reds. The advice is given for Leghorn breeders to breed their birds well up to standard weight.

Results Obtained in the Present Experiment. The coefficients of correlation between the mean body weights and the number of eggs produced were as follows:

Eggs laid first year and body weight same year:------ r=+.106±.050
Eggs laid second year and body weight second year: r=+.125±.050
Eggs laid third year and body weight third year:----- r=—.127±.052

None of these coefficients is significant, since they are only about twice as great as their probable errors. These results considered in connection with the results reported above, disregarding for the

moment the results derived from the Egg-Laying Contests, strongly support the conclusion that there is no relationship between the body weight of Leghorns and the number of eggs which they may lay. In the case of the data from the Egg-Laying Contests, which are in more or less direct disagreement with this conclusion, it should be pointed out that the birds in these contests were developed under very diverse conditions with reference to breeding and feeding, and unquestionably some of them were considerably younger than others when the contests began. Hence it appears that the body weights on which this correlation was based were influenced by the different ages of the birds, and the results as shown in Table 6 may indicate merely that the more mature and better developed birds laid better during their pullet year than their less mature and less well-developed and consequently smaller competitors.

Correlation between Age at First Egg-Laying and Annual Production

In a flock of pullets in which the birds are all of the same age, some will begin to lay considerably earlier in the fall than others. The question whether such individuals are better layers than those which reach sexual maturity more slowly has received considerable attention from poultry investigators.

Kempster *(1925)* in his bulletin on "The Correlation between Sexual Maturity and Egg Production" refers to the work of 11 other investigators and presents the results of 6 years' work at the Missouri Station.

TABLE 7.—*Correlation Between Age at First Egg-Laying and Annual Production Found at the Missouri Station*

Year	Number of Birds	Coefficient of Correlation	Mean Egg Production	Mean Days To Mature
1917-18	95	—.3182±.063	143.62±2.34	232.76±2.04
1918-19	133	—.4448±.044	151.16±2.03	256.3±1.97
1919-20	152	—.2846±.051	153.95±2.09	198.34±1.82
1920-21	237	—.4228±.037	148.83±1.65	218.51±1.46
1921-22	152	—.3637±.048	149.93±1.78	249.67±1.70
1922-23	224	—.2339±.043	146.74±1.76	232.7±1.50

Table 7 shows the correlation coefficients between the rate of maturity and the annual egg production as obtained at the Missouri Station. This table shows a significant negative correlation between rate of sexual maturity and annual egg production for each of the 6 years. There also was found a still higher negative correlation between rate of sexual maturity and winter egg production. Hence the birds which begin to lay earliest in the fall make better winter layers and lay better during the first or pullet year than the birds which mature more slowly.

It is important to know whether the superior production of the early maturing birds extends beyond the pullet year. The present investigation is intended to shed some light on this question. The

correlation coefficients based on the 165 birds that finished the third year were as follows:

First year: —.459±.041
Second year:—.107±.052
Third year: —.063±.052

The coefficient for the first year is negative and significant and agrees with the results obtained by Kempster and several other in-

TABLE 8.—*Constants Obtained for the First Three Years in a Study of Certain Normal Characteristics of White Leghorn Females*

Character	Mean	Standard Deviation	Coefficient of Variability
First year—178 birds			
Egg production	170.22±2.04	40.33±1.44	23.69±2.96
Egg weight	53.24±.17	3.28±.12	6.16±.29
Body weight	3.46±.01	.28±.01	8.01±.43
Second year—178 birds			
Egg production	135.98±1.88	37.08±1.33	27.27±3.87
Egg weight	56.88±.17	3.39±.12	5.96±.28
Body weight	3.99±.02	.37±.01	9.35±.78
Third year—165 birds			
Egg production	106.15±1.90	35.99±1.34	33.90±5.92
Egg weight	56.51±.18	3.44±.13	6.09±.30
Body weight	4.26±.02	.43±.02	10.08±.92

TABLE 9.—*Correlation Coefficients Obtained between Certain Normal Characteristics of White Leghorn Females*

Characters	Year	178 Birds	165 Birds
Egg production	Between first and second	r=+.382±.043	
	Between first and second		r=+.473±.041
	Between first and third		+.357±.046
	Between second and third		+.561±.036
Egg weight	Between first and second	+.861±.013	
	Between second and third		+.903±.010
Body weight	Between first and second	+.827±.016	
	Between second and third		+.918±.008
Production and egg weight	First year	+.180±.049	
	Second year	+.052±.050	
	Third year		+.044±.052
Production and body weight	First year	+.106±.050	
	Second year	+.125±.050	
	Third year		—.127±.052
Egg weight and body weight	First year	+.458±.040	
	Second year	+.434±.040	
	Third year		+.426±.043
Days maturing and number of eggs laid		(188 birds)	
	First year	—.403±.041	—.459±.041
	Second year		—.107±.052
	Third year		—.063±.052

vestigators, but the coefficients for the second and third years are not significant, and indicate that there is no connection between early maturity and the number of eggs laid during the second and third years.*

Tables 8, 9, and 10 bring together in convenient form for reference the principal means, deviations, and correlations found in the present investigation.

TABLE 10.—*Percentage Increase or Decrease in Production, Egg Weight, and Body Weight of White Leghorn Females*

Characters	Decrease or Increase	Year	Percent
Number of eggs produced	Decrease	First to second	20.12
	Decrease	Second to third	21.94
Mean egg weight	Increase	First to second	6.82
	Decrease	Second to third	.70
Body weight	Increase	First to second	15.13
	Increase	Second to third	6.26
Total weight of eggs laid	Decrease	First to second	14.4
	Decrease	Second to third	22.25

SUMMARY AND CONCLUSIONS

In this experiment the influence of senescence decreased the egg production from the first to the second year 20 percent, and from the second to the third, 22 percent. This result when considered in connection with the results of other investigations shows that when Leghorns are maintained under average conditions the decrease in egg production due to increasing age is, in round numbers, 20 percent per year.

The average weight of the eggs laid during the pullet year was 53.24±.16 grams, during the second year, 56.87±.17 grams, and during the third year, 56.50±.18 grams. There was no significant change in egg weight from the second to the third year, but from the first year to the second year there was an increase of 6.8 percent.

The average weight of the eggs laid per bird was 9,029 grams for the first year, 7,726 grams for the second year, and 6,008 grams for the third year. The decrease from the first to the second year was 14.4 percent and from the second to the third year, 22.2 percent.

During the pullet year the eggs increased in weight with a fair degree of uniformity from the beginning of the laying year to its close. During the two following years the heaviest eggs were laid in December and the lightest eggs in July.

Egg production was at its maximum intensity in April and May and at its lowest in November and December.

The average weight of the birds during the pullet year was 3.46 pounds, for the second year 3.99 pounds, and for the third year 4.25 pounds. The increase in weight from the first to the second year was 15.3 percent and from the second to the third year, 6.52 percent.

*If this result should be confirmed by later studies it will be helpful to determine why this relationship should exist between early maturity and egg production during the first year and not later.

During the pullet year the birds increased in weight with fair regularity from the beginning of the year to its close.

During the two following years the birds were lightest in weight during November and December and, in general, heaviest in March and April.

The correlations for the different years in the number of eggs laid per year were significant in all cases, showing that a reasonably good layer the first year would probably be a reasonably good layer during later years. The coefficients of correlation, however, are not large, showing that various factors are involved in determining the number of eggs that a bird may lay from year to year.

The correlations for the different years in the mean annual egg weights were highly significant in all cases, showing that the weight of the eggs laid by a bird is a relatively stable character, persisting from year to year.

The coefficients of correlation between body weight and egg weight were significant in all cases, showing that the heavier birds laid the heavier eggs.

The birds became somewhat more variable in body weight as they became older, but there was no evidence to show that the birds which became materially heavier with increasing age were either better or poorer layers than their companions which remained lighter in weight.

The size of the eggs laid by a flock may be increased by culling out the smaller pullets in the fall.

There was no connection between the number of eggs laid by a bird and the mean weight of the eggs. A bird which lays a large number of eggs is as likely to lay large eggs as small ones.

There was no connection between the mean body weights of the birds and the number of eggs laid. A small pullet is as likely to lay a creditable number of eggs as her larger companion.

The younger the pullet when beginning to lay, the better the egg production for the pullet year. This relationship did not hold true during later years.

LITERATURE CITED

ATWOOD, H., and WEAKLEY, C. E., JR.
1917. CERTAIN CHARACTERISTICS OF HEN EGGS. W. Va. Agr. Exp. Sta. Bul. 166.

ATWOOD, H.
1923. INFLUENCE OF RATIONS FED TO GROWING CHICKS ON THE CHARACTERISTICS OF THE ADULT FEMALES. W. Va. Agr. Exp. Sta. Bul. 179.

———
1923. CERTAIN CORRELATIONS IN THE WEIGHT AND NUMBER OF EGGS AND THE WEIGHT OF FOWLS. W. Va. Agr. Exp. Sta. Bul. 182.

———
1925. THE STANDARD DEVIATION IN THE WEIGHT OF WHITE LEGHORN EGGS. W. Va. Agr. Exp. Sta. Bul. 195.

———
1926. SOME FACTORS AFFECTING THE WEIGHT OF EGGS. W. Va. Agr. Exp. Sta. Bul. 201.

BALL, E. D., ALDER, B., and EGBERT, A. D.
1916. BREEDING FOR EGG PRODUCTION. PART I. Utah Agr. Exp. Sta. Bul. 148.

BRODY, S., HENDERSON, E. W., and KEMPSTER, H. L.
1924. THE RATE OF SENESCENCE OF THE DOMESTIC FOWL AS MEASURED BY THE DECLINE IN EGG PRODUCTION WITH AGE. Jour. Gen. Phys. VI: 41-45.

HADLEY, P.
1919. EGG WEIGHT AS A CRITERION OF NUMERICAL PRODUCTION IN THE DOMESTIC FOWL. Amer. Nat. LIII, Sept.-Oct. 1619.

HERVEY, G. W., and LEWIS, H. R.
1924. THE RELATION OF EXTERNAL BODY CHARACTERS TO ANNUAL PRODUCTION IN BARRED PLYMOUTH ROCKS. Poult. Sci. III, 3.

JULL, M. A.
1924. EGG WEIGHT IN RELATION TO PRODUCTION. Poult. Sci. III, 5.

—
1928. SECOND YEAR EGG PRODUCTION IN RELATION TO FIRST YEAR PRODUCTION IN THE DOMESTIC FOWL. Poult. Sci. VII, 6.

KEMPSTER, H. L.
1925. THE CORRELATION BETWEEN SEXUAL MATURITY AND EGG PRODUCTION. Mo. Agr. Exp. Sta. Res. Bul. 78.

LEWIS, H. R., HANNAS, R. R., and WENE, E. H.
1919. THE FIRST TWO YEARS OF THE VINELAND CONTEST. N. J. Agr. Exp. Sta. Bul. 338.

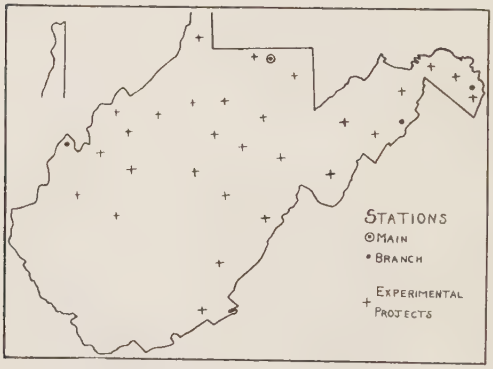
PARKHURST, R. T.
1926. CERTAIN FACTORS IN RELATION TO PRODUCTION AND EGG WEIGHT IN WHITE LEGHORNS. Poult. Sci. V, 3.

PLATT, C. S.
1927. RELATIONSHIP BETWEEN BODY WEIGHT AND EGG PRODUCTION IN THE DOMESTIC FOWL. Poult. Sci. VI, 6.

REPORT OF THE SIXTH, SEVENTH, AND EIGHTH ANNUAL CANADIAN NATIONAL EGG-LAYING CONTESTS.
1929. Dominion of Canada, Dept. of Agr. Bul. 180 (new series).

SHERWOOD, R. M.
1922. CORRELATION BETWEEN EXTERNAL BODY CHARACTERS AND ANNUAL EGG PRODUCTION IN WHITE LEGHORN FOWLS. Texas Agr. Exp. Sta. Bul. 295.

AGRICULTURAL EXPERIMENT STATION



WEST VIRGINIA UNIVERSITY

Bulletin 234 June, 1930

Standardization of Cherry and Blackberry Preserves and Blackberry Jelly

by HAZEL CAMERON and RUTH B. BURNS

UNIVERSITY OF ARIZONA LIBRARY

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

LITERATURE CITED

(1) Association Official Agricultural Chemists.
1925. official and tentative methods of analysis. Ed. 2.

(2) Cruess, W. V.
1924. commercial fruit and vegetable products. Ed. 1, 2nd impression. New York.

(3) ———, and McNair, J. B.
1916. jelly investigations. Jour. Ind. and Eng. Chem. 8:417.

(4) Goldthwaite, N. E.
1909. principles of jelly making. Jour. Ind. and Eng. Chem. 1:333.

(5) ———
1910. principles of jelly making. Jour. Ind. and Eng. Chem. 2:457.

(6) ———
1914. principles of jelly making. Univ. of Ill. Bul. 31, vol. xi.

(7) ———
1925. principles of making fruit jellies. Col. Agr. Exp. Sta. Bul. 298

(8) Myers, P. B., and Baker, G. L.
1926. fruit jellies. iv. the role of salts. Del. Agr. Exp. Sta. Bul. 144, Tech. No. 7.

(9) McNair, J. B.
1916. consistency of pectin jells. Jour. Phys. Chem. 20:633.

(10) Nelson, E. K.
1925. non-volatile acids of blackberries. Jour. Amer. Chem. Soc. 47:568.

(11) Singh, L.
1922. a study of pectin and acidity in jelly making. Jour. Ind. and Eng. Chem. 14:710.

(12) Tarr, L. W.
1923. fruit jellies. i. role of acids. Del. Agr. Exp. Sta. Bul. 134, Tech. No. 2.

(13) ——— and Baker, G. L.
1924. fruit jellies. ii. role of sugar. Del. Agr. Exp. Sta. Bul. 136, Tech. No. 3.

(14) ———
1926. fruit jellies. iii. jelly strength measurements. Del. Agr. Exp. Sta. Bul. 142, Tech. No. 5.

(15) United States Department of Agriculture.
1927. service and regulatory announcements. Food and Drug No. 2.

(16) ———
1917. home canning of fruits and vegetables. Farmers' Bulletin 853.

(17) ———
1923. home made apple and citrus pectin extracts and their use in jelly making. Dept. Circ. 254.

*Standardization of Cherry and Blackberry Preserves and Blackberry Jelly**

by HAZEL CAMERON and RUTH B. BURNS†

THE MAKING of an ideal preserve or jelly is far from being standardized, either in the home or among commercial manufacturers. One reason lies in the complexity of the problem involved in the jellying or thickening of fruit juices, including as it does the colloid chemistry of the little-understood pectic substances. The present investigation was undertaken with the aim not of studying the underlying scientific principles, but of arriving as speedily as possible at a satisfactory method for cherry and blackberry preserves and blackberry jelly, and of utilizing a surplus of fruit existing in certain parts of the state where a satisfactory market was not available for the fresh fruit. The fruit used was obtained from the University farm and other farms in and near the vicinity of Morgantown, the greater part being available within a few hours after picking.

Standardization of Cherry Preserves

Standard Preserves

The United States Department of Agriculture *(15)* defines a preserve or jam as "the clean, sound product made by cooking to a suitable consistence, properly prepared fresh fruit, cold pack fruit, canned fruit, or a mixture of two or all of these, with sugar, or with sugar and water. In its preparation not less than 45 pounds of fruit are used to each 55 pounds of sugar. A product in which the fruit is whole or in relatively large pieces is customarily designated a preserve rather than a jam." Preserves may be made according to this standard and still be far from ideal. An ideal cherry preserve should retain the original shape of the cherry and the natural cherry color and flavor, with an agreeable tartness; should contain cherries whole and plump, with tender, unshriveled skins; in a clear syrup, not caramelized, of high concentration of sugar; should have a consistency that is not a jelly; yet should not "run" on a plate. *(2)*

Attainment of such an ideal preserve from cherries is complicated by 1) lack of pectin to give desirable thickness to the syrup; 2) toughness of skin in some varieties; 3) loss of shape in heating; and 4) lack of sufficient acid in some varieties to yield the necessary tartness. The following factors also are of importance in cooking as affecting the character of the product: amount of sugar, method of adding sugar, temperature of cooking process, variety of cherry, and maturity of cherry. Experimental work was therefore conducted involving the effect of variations of these factors in developing a standard method for cherry preserves.

*Recommendations embodied in the present discussion are outlined in Circular 55, "Blackberry Jelly, Blackberry Jam, and Cherry Preserves," by Hazel Cameron, published by and available upon request from the Agricultural Experiment Station, Morgantown, W. Va.

†Mrs. Burns resigned October, 1926.

Amount of Sugar

The simplest proportion of sugar to cherries employed, complying with the United States Government standard for preserves, was the 50-50 ratio, i. e., equal weights of pitted cherries and sugar. Preliminary work on canned cherries indicated a temperature of 106° C. as the probable optimum for cherry preserves. Equal weights of washed, pitted cherries and sugar were therefore cooked together to 106° to serve as a standard for comparison. Varying amounts of sugar were also tried, ranging from 45 percent sugar (a ratio of 45 parts of sugar by weight to each 55 parts of cherries), an amount slightly below the maximum proportion permitted by the government standard, to 60 percent by weight of sugar.

Table 1 gives the results of this series of trials. It will be noted that 1) the color is noticeably paler with the larger amounts of sugar; 2) the syrup becomes thinner and spreads more freely; 3) the preserve is too sweet for the average taste with the larger amounts of sugar unless acid is added; 4) the product is too thin to be ideal, the cherries being distributed through a large proportion of syrup; and 5) the yield increases slightly with the increased amounts of sugar. The lower proportion of sugar was therefore judged to be more satisfactory, and the 50-50 ratio was used as a convenient standard.

Method of Adding Sugar

In the preparation of preserves two general methods are used for the addition of the sugar:

1. The sugar is made into a syrup in which the fruit is cooked.
2. Dry sugar is added to the fruit and cooked to the desired consistency.

The first method is usually regarded as best for retaining the shape of the fruit, particularly for berries *(16)*. Since cherries, having a thicker skin, show a tendency to shrink considerably when introduced into syrups of heavy sugar concentration, a thin syrup was made from one cup sugar and two cups water, boiled one minute, then cooled. In this syrup the washed, pitted cherries were allowed to stand 18 to 24 hours. The juice was then drained off and enough additional sugar added to make the total weight of sugar equal to the weight of pitted cherries. This was heated to boiling, when the cherries were dropped in and cooked to temperature. Trials were also made with heavy syrups (3 cups sugar to 2 cups water) in which the cherries stood 18 to 48 hours. The cherries showed little shrinkage during soaking or cooking, but during cooling, as the syrup penetrated the cherries, they shriveled decidedly. The resulting product also contained an undesirably large proportion of syrup not absorbed by the cherries, and for these two reasons the method was abandoned in favor of the second method.

The effect was tried next of adding the dry sugar in small increments at intervals of 2 to 18 hours and heating to 82° C. with each addition of sugar. Washed pitted cherries were allowed to stand over night in the refrigerator with one-fourth their weight of sugar. In the morning they were heated again to 82° with an additional one-fourth weight of sugar, and allowed to stand from 2 to 8 hours, when another

TABLE 1.—*Effect on Cherry Preserves of Varying the Proportion of Sugar to Cherries*

Variety of Cherry	Score	25% Sugar 106° C.	Standard 50% Sugar 106° C.	55% Sugar 106° C.	60% Sugar 106° C.	45% Sugar 107° C.	50% Sugar 107° C.	55% Sugar 108° C.	60% Sugar 108° C.
Early Richmond Unripe	COLOR	Faded red	Faded red	Faded red					
	SYRUP	Inclined to jell	Very good consistency	Good consistency					
	FLAVOR	Slightly puckery	Slightly puckery	Puckery					
	TEXTURE	Good	Good	Good					
Early Richmond Ripe	COLOR	Darker than standard	Good	Lighter than standard	Lighter than 55% sugar			Darker than standard	Darker than standard
	SYRUP	Very good consistency	Slightly thin	Thinner than standard	Too thin			Thicker than standard	Thinner than standard
	FLAVOR	Good	Good	Too sweet	Too sweet			Too sweet	Too sweet
	TEXTURE	Good	Good	Good	Good			Good, but tougher than at 106°	Good, but tougher than standard
Mont-morency	COLOR	Darker than standard	Good	Lighter than standard	Lighter than 55%				
	SYRUP	Thicker than standard	Good consistency	Thinner than standard	Too thin				
	FLAVOR	Strong	Good	Too sweet	Too sweet				
	TEXTURE	Good	Good	Good	Good			55% Sugar 107° C.	60% Sugar 107° C.
Mont-morency	COLOR	Darker than standard	Good	Lighter than standard	Lighter than 55%	Darker than standard at 106° C. Lighter than standard at 107° C.	Slightly darker than standard	Darker than 106° standard Lighter than 107° standard	Lighter than 55% at 107° Darker than 55% at 106°
	SYRUP	Thicker than standard	Good consistency	Good consistency	Good consistency	Good	Good consistency	Good consistency	Too thin
	FLAVOR	Good	Good	Good	Too sweet	Strong	Good	Strong	Too sweet
	TEXTURE	Good	Good	Good	Good	Good	Good	Good	Good
English Morello	COLOR	Dark red	Dark red	Lighter than standard	Lighter than 55%	As above	Darker than standard	Lighter than 55% at 107°	Lighter than 55% at 107°
	SYRUP	Good consistency, Thicker than standard	Good consistency	Thinner than standard	Too thin	Good	Thicker than standard	Thinner than 50% at 107°	Thinner than 55% at 107° and standard
	FLAVOR	Strong	Sligthly bitter, disappears on standing	Good	Too sweet	Strong	Good	Good	Too sweet
	TEXTURE	Good	Good	Good	Good	Good	Good	Good	Good

TABLE 2.—*Effect of Temperature in Making Cherry Preserves*

Variety of Cherry	106° C.	107° C.	108° C.	109° C.	110° C.
Early Richmond	COLOR good SYRUP tendency to be thin FLAVOR good TEXTURE good	COLOR slightly darker than standard SYRUP a little more concentrated than standard but good FLAVOR good TEXTURE good	COLOR slightly darker than at 107° SYRUP a little more concentrated than at 107° but still good FLAVOR good TEXTURE skins are a little tough	COLOR slightly darker than at 108° SYRUP inclined to be sticky and gummy	COLOR darker than 109° SYRUP like candy FLAVOR good but cherries are candied TEXTURE cherries are shriveled and the skins are tough
Montmorency	COLOR good SYRUP good consistency FLAVOR good TEXTURE good	COLOR slightly darker than standard SYRUP more concentrated than standard and better FLAVOR good TEXTURE good	COLOR slightly darker than at 107° SYRUP tends to become sticky and gummy FLAVOR cherries taste more candied than preserved TEXTURE shriveled and tough skins	COLOR slightly darker than 108° SYRUP tendency to be too sticky and gummy FLAVOR too sweet Tastes candied rather than preserved TEXTURE skins shriveled and tough	
Montmorency	COLOR good SYRUP good consistency FLAVOR good TEXTURE good	COLOR slightly darker than standard SYRUP good consistency FLAVOR good TEXTURE good	COLOR slightly darker than at 107° SYRUP little too concentrated FLAVOR good TEXTURE cherries shriveled and skins tough	COLOR slightly darker than 108° SYRUP very much like Karo corn syrup FLAVOR too sweet TEXTURE cherries are shriveled and tough	
English Morello	COLOR dark red SYRUP unusually good consistency FLAVOR slight bitter taste when first made but it disappeared on standing TEXTURE good	COLOR darker than standard SYRUP more concentrated than standard FLAVOR good, stronger than standard TEXTURE good	COLOR slightly darker than at 107° SYRUP more concentrated than standard but good FLAVOR strong and tends to leave a burning taste TEXTURE tough skins and shriveled	COLOR slightly darker than at 108° SYRUP concentrated good FLAVOR strong and tends to leave a burning taste but not as bad as at 108° TEXTURE tough and shriveled skins	

NOT SO MARKED A COLOR GRADATION AS IN OTHER VARIETIES—DARK COLOR

TABLE 2.—*Effect of Temperature in Making Cherry Preserves*—CONTINUED

Dyehouse	COLOR good SYRUP tendency to be thin FLAVOR good TEXTURE good	COLOR darker than standard SYRUP good FLAVOR good TEXTURE good	COLOR slightly darker than at 107° SYRUP like Karo corn syrur FLAVOR a little sweet TEXTURE good	COLOR slightly darker than at 108° SYRUP like Karo syrup FLAVOR too sweet TEXTURE good	
May Duke	COLOR good SYRUP too thin FLAVOR too sweet TEXTURE good 100 LEMON JUICE	COLOR slightly darker than standard SYRUP more concentrated than standard but good FLAVOR good TEXTURE good	COLOR slightly darker than at 107° SYRUP similar to Karo but possibly not objectionable FLAVOR little too sweet TEXTURE skins shriveled and tough		

NOTE: To 1000 gm. of pitted cherries, 1000 gm. of sugar was added and heated to various temperatures. Yield was approximately 2 pts. in each case.

one-fourth portion of sugar was added. Again they were allowed to stand 2 to 8 hours. With final addition of sugar the preserves were heated to 106° and sealed into jars.

The preserves made by adding sugar at 2-hour intervals were deemed equally as good in tenderness, consistency, and retention of shape without shriveling, as those involving a longer interval of time.* There was less shriveling of skin and less shrinking of cherries in this method than when the sugar was added in one portion, particularly in the case of sweet cherries. However, since standing extracts more juice, the consistency of the product was a little thin when not altered by the addition of pectin in some form or by discarding part of the juice. From one-half to one cup of syrup from 1000 gms. of cherries can be discarded in sealing the preserves, and used as a sauce for ice cream or puddings, or in lemonade. This leaves a preserve with less juice and with very desirable consistency.

Effect of Temperature Variations

The effect on consistency of varying the temperature is shown in Table 2. With the standard method as outlined, equal weights of pitted cherries and sugar were heated to temperatures of from 106° to 110° C., at 1-degree intervals. Temperatures below 106° usually yielded a consistency too thin to be termed a preserve. It was found that increasing the temperature 1) darkens the color of the preserves, 2) increases the thickness of the syrup, and 3) shrivels and toughens the skins of the cherries. Temperature of 106° to 106.5° was therefore judged most satisfactory for general use.

Cooking cherry preserves to temperature is subject to considerable inaccuracy since the mixture is not homogeneous; yet it has been the only known improvement over the "inspection" method in the home. The commercial method of cooking a product until its final weight

*All preserves were scored by a committee of three to five judges.

bears a certain relation to its original weight—known as the "percent of kettle yield"—offered some promise for household use. Therefore, the final end weight of cherry preserves was taken when a temperature of 105° to 107° C. was reached.

The average percentage of kettle yield for each variety for the years 1927 and 1928 is given in Table 3, together with the number of tests from which the average is taken. In Table 4, averages are given for those products only which scored "good", for the years 1927 and 1928, at temperatures of 105° to 107° C., the majority at 106°. It will be seen that for the products rated "good", the average for all varieties is 79 and 81, respectively, for 1927 and 1928.

TABLE 3.—*Kettle Yield in Percent for All Cherry Preserves at Temperatures of 105° to 107° C.*

Variety	1927		1928	
	Percent	Number of Trials	Percent	Number of Trials
Early Richmond	80.2	10	83	10
Montmorency	76.7	29	83.7	28
Dyehouse	.....	....	77	6
May Duke	.....	....	76	9
Average	77.5		79.9	

The average percentage for May Duke and Dyehouse cherries was somewhat lower, but the number available was small; the bulk of the cherries used for experimental work in the homes throughout the state being either Early Richmond or Montmorency, particularly the latter. For 1929, therefore, the figure 85 was used as the trial percentage of kettle yield. Cherry preserves were cooked to that figure, and the temperature recorded. Of 30 tests, all scored good, recording a temperature of 105.5° to 107° C.; 88.8 percent indicating a temperature of between 106° and 106.5°. For Montmorency cherries at least, therefore, a kettle yield of 83 to 85 percent yields a satisfactory product. The end weight desired is calculated at the beginning by taking 83 or 85 percent of the combined weight of cherries and sugar. Frequent weighings may be necessary to attain the exact point desired but with practice, only two may be necessary, obviating the use of a thermometer and the stirring it necessitates.

Effect of Adding Pectin

Since increasing the thickness of cherry preserves through increase of temperature shrivels the fruit undesirably, the effect was tried of thickening by means of added pectin. Three types of pectin were used: *(1)* homemade apple pectin, *(2)* commercial pectin solution, and *(3)* powdered apple pectin.*†

Homemade pectin solution, obtained from apples by the method of Denton, Johnstin, and Yeatman *(17)*, was prepared for experimental work. Analysis of the pectin solution made from apples by this method and of a commercial liquid pectin gave the following percentages for pectic substance: *(1)*

*NUTRL-JEL, supplied by Speas Manufacturing Co., Kansas City, Mo.

†The term pectin here is used in the sense defined by the American Chemical Society as "water-soluble methylated pectic substance—obtained by the restricted hydrolysis of the protopectin occurring naturally in plant tissues." Protopectin is the gelatinizable parent substance, found in fruits and succulent edible vegetables, which on boiling with water yields pectin—the substance which gives to fruit juices their "jellying" property.

	Alcohol Precipitate	*Pectic Acid*
Homemade apple pectin	1.09 percent	0.73 percent
Commercial apple pectin	3.08 percent	1.56 percent

It is evident therefore that homemade apple-pectin solution was more dilute as regards pectic substances than the commercial and would require a larger amount to produce the same consistence. This is borne out by the findings given below.

Commercial and homemade apple pectin solutions were used in similar manner. Equal weights of washed pitted cherries and sugar (1000 grams of each) were heated quickly to 106° C. Pectin solution was added in the amounts given in Tables 5 and 6. The mixture was allowed to boil 1 minute, then to stand 5 minutes before skimming and sealing into jars. Both the commercial and homemade apple pectin solutions were used in amounts of 25, 50, and 100 c.c. per 1000 gm. of cherries. In addition, a full bottle of each (200 c. c. or about 1 cup) was used as follows:

> One thousand gm. of pitted cherries were simmered in a small amount of water for 10 minutes, when 1470 gm. of sugar was added, and the whole quickly brought to the boiling temperature and boiled one minute. The pectin solution was added at this point and allowed to stand 5 minutes with frequent stirring, then skimmed and sealed. Since this product was judged too sweet as well as decidedly too stiff, the former method was substituted.

The yield of preserves in which the larger amount of sugar was used was about 3 pints; with a smaller amount of sugar (equal weights of cherries and sugar), either with or without amounts of pectin varying from 25 to 100 c. c., the yield was 2 pints. In other words, the yield is dependent on the amount of sugar used. Larger amounts of sugar necessitate pectin for thickening. The cherries in this product are suspended in a larger amount of juice, which is economical only if the sugar used is cheaper than the cherries. Since the larger amount of sugar was found too sweet for the average taste, equal weights of cherries and sugar were subsequently used, with the addition of small

TABLE 4.—*Kettle Yield in Percent for Cherry Preserves at 105° to 107° C., Rated as "Good"*

Variety	1927		1928	
	Percent	Number of Trials	Percent	Number of Trials
Early Richmond	79	5	84	7
Montmorency	79	2	83.9	21
Dyehouse	....	....	76.8	6
May Duke	....	....	77.8	5
Average	79		81.1	

amounts of pectin solution when greater thickness was desired (see Table 5).

In some instances the preserves made with the commercial pectin solution, although at first too stiff, after standing 2 or 3 months became too thin to be classed as preserves. No satisfactory explanation can be given for this phenomenon. The work of Tarr, Myers, and Baker at

the Delaware Station *(8, 12, 13)* suggests that the hydrogen-ion concentration is probably an important factor. Little if any difference could be detected in preserves boiled one minute after the addition of pectin and in those merely allowed to stand 5 minutes. The color of the preserves, however, was considerably darker, and the flavor less natural, when the pectin solution was added at the beginning of the cooking process. The most satisfactory method therefore seems to be to add the pectin just at the end of boiling. Preserves which were allowed to stand in the kettle until cold, with frequent stirring, showed better consistency and greater plumpness, whether with or without added pectin. This standing interval is therefore recommended.

Dry apple pectin when used was mixed thoroughly with an equal amount of sugar, added slowly to a part of the juice of the cherries at boiling point and boiled until dissolved, then added to the cherries and the remainder of the sugar. The whole then was cooked to 106° as before. The total amount of sugar was kept equal to the weight of pitted cherries. Quantities of dry pectin, from 14 to 20 gm. per 1000 gm. of cherries, were used with the results as given in Tables 5 and 6.

From these results it was concluded that for sour cherries 30 to 40 c.c. of commercial apple pectin solution per 1000 gm. of cherries,

TABLE 5.—*Effect on Cherry Preserves of Additions of Commercial Pectin Solution*

Kinds of Cherries	Items Scored	Amount of Pectin per 1000 Grams of Cherries				
		200 c.c.	100 c.c.	45-50 c.c.	30-35 c.c.	25 c.c.
Sour Cherries 106° C.	Color	Lighter than standard	Darker than standard	Darker than standard	Good	Darker than standard
	Syrup	Stiff when made, thin on standing	Jelly	Soft Jelly	Usually good Sometimes thin	Good consistency
	Flavor	Milder than standard	Milder than standard	Milder than standard	Good	Milder than standard
	Texture	Good	Good	Good	Good	Good
	Varieties	Early Richmond, Montmorency	Early Richmond, Montmorency, Eng. Morello	[1] Early Richmond, Montmorency, Eng. Morello, May Duke, Dyehouse	[2] Early Richmond, Montmorency, May Duke, Dyehouse	Early Richmond, Montmorency, Eng. Morello
105° C.	Consistency	.....	Soft Jelly	Good	Good	.....
	percent Juice	.....	.....	Good	Good	.....
	Variety	.....	Early Richmond	Montmorency	Montmorency	.....
Sweet Cherries	Color	.....	.....	Good	Good	.....
	Syrup	.....	.....	Jelly	Good	Good (a little thin)
	Flavor	.....	.....	Good	Good	.....
	Texture	.....	.....	Good	Good	Good
	Proportion of juice	.....	.....	.....	Sl. too much	Good
	Varieties	.....	.....	[3] Sd. Blackheart, Sd. Redheart	Sd. Blackheart, Sd. Redheart	Sd. Blackheart, Sd. Redheart

[1] Slight bitter taste, disappears on standing.
[2] In some cases grew thin on standing.
[3] Flavor improved by 11 c.c. 4% citric acid. Flavor less good with 22 c.c. citric acid.

TABLE 6.—*Effect on Cherry Preserves of Additions of Homemade and Dry Apple Pectin*

Kind	Score	Amounts of Pectin per 1000 gm. of Cherries					
		Home Made Solution			Dry Powder		
		200 c.c.	100 c.c.	50 c.c.	15 gm.	20 gm.	30 gm.
Sour Cherries	Color	Good	Good	Same	.....	.....	.....
	Syrup	Tendency to Jelly	Sl. thicker than standard	Same	Thin	.....	.....
	Flavor	Good	Good	Standard	.....	.....	.....
	Texture	Good	Good		Too much juice	.....	.....
	Varieties	Early Richmond, Mont-morency, Eng.Morello	Early Richmond, Mont-morency, Eng.Morello, May Duke	Early Richmond, Mont-morency, Eng.Morello			
Sweet Cherries		Good	.....	Good	Good (11 c.c. acid)	Good	Stiff and gummy

or 100 c.c. of homemade apple-pectin solution, improved the consistency of the preserves without injuring the flavor. For sweet cherries, 11 c.c. of 4 percent citric acid and 25 to 35 c.c. commercial apple-pectin solution or 15 to 20 gm. of powdered apple pectin, improved the product. These amounts did not noticeably alter the natural cherry flavor of the preserve. Larger amounts gave products too stiff and jelly-like for a preserve. Results were somewhat variable, however, as some of the thickest preserves became thin on standing.

Assuming that the content of alcohol precipitate is a measure of the pectin content and hence of the thickening power of pectin solution, one would expect to require 2.82 times as much of the homemade apple-pectin solution used in this work, as of the commercial product, since the latter gave 3.8 percent alcohol precipitate, as against 1.09 percent for the former (2.82 times as much). Actually this was found true, as 100 c.c. of homemade apple-pectin solution gave approximately the same consistency as 25 to 35 c.c. of the commercial. Homemade solutions would of course vary with the degree of concentration reached in preparation as well as with the variety of apple, storage time, and other factors.

Effect of Variety

Varieties used included Early Richmond, Montmorency, Dye House, English Morello, Seedling Redhearts, Seedling Blackhearts, and May Duke. Chemical analyses of all except the last three varieties are given in Table 7. The best preserves were obtained from partially ripe Early Richmonds, from Montmorency, May Duke, and English Morello; in other words, from those varieties richest in pectin and acid. The English Morello was especially desirable, the pectin and acid content of its juice being sufficiently high to make a real jelly when sugar was combined with it in the proportion of one-half measure of sugar to one measure of juice. The strong, slightly bitter taste at first noticeable in these preserves disappears entirely on standing. A dark, rich red preserve of desirable consistency and flavor results.

TABLE 7.—*Chemical Analyses of Cherries*

Variety of Cherry	Stage of Ripening	Alcohol Precipitate	Pectic Acid	Total Solids	Total Ash	Invert Sugar	Balling 60° F.	Acidity—c.c. N/10 Alk. to neutralize 100 gm.
		percent	*percent*	*percent*	*percent*	*percent*	*percent*	
Early Richmond	unripe	.1918	.1184	10.14	.595	10.27	15.98	234.6
Early Richmond	ripe	.238	.1459	27.18	.757	10.39	20.13	230.7
Montmorency	unripe	.1676	.0809	35.8	.4002	7.19	14.97	194.6
Montmorency	ripe	.280	.145	.....	.483	10.17	17.9	271.2
English Morello	unripe	.380	.235	46.4	.498	8.17	16.72	546.6
English Morello	ripe	.257	.169	.....	.471	9.09	14.04	364.0
Dyehouse	overripe	.197	.565	23.25	.634	10.29	14.58	189.3
Sweet Cherries	ripe	.271	.169	28.98	.856	15.09	.....	408.0

Seedling Blackhearts and Redhearts show an undesirably tough skin, not improved by preserving, and require the addition of acid to bring out the best flavor and texture. Blackhearts, in spite of tough skin, made a well-liked preserve, however, when prepared according to the method recommended with addition of 11 c.c. of 4 percent citric acid at the end of cooking. Some of the early sour cherries have a large seed and thin soft pulp which will not yield whole, plump fruit for preserving. These are likely to be broken up in cooking and are therefore better used for canning or for combining, whole or ground, with other fruits for marmalade.

Effect of Maturity

The effect of maturity of fruit for cherry preserves was tried on two varieties, Early Richmond and English Morello, for which unripe cherries were available. According to the theory of its formation, pectin should be more abundant in unripe than in ripe fruit. The alcohol test for pectin (equal measures of alcohol and cooked fruit juice) and chemical analysis both attest this theory. Preserves therefore were made using 25, 50, 75, and 100 percent partly ripe cherries of the varieties mentioned. For early Richmond the color was found to grow lighter with each successive 25 percent addition of unripe cherries. With 100 percent of partly ripe cherries the juice of the preserves was colored only a light faded red. For English Morello the opposite was true, the color deepening with each successive 25 percent addition of unripe fruit (Table 8). The concentration of the juice increased with the unripe fruit, but the skins showed a tendency toward toughness. Therefore, while slight improvement in consistency was obtained by the use of 25 to 50 percent of unripe fruit, the toughness of skin and the slightly bitter taste rendered such addition undesirable. In general, variations in ripeness made greater differences in preserves than did differences in varieties among sour cherries.

Subsequent work on Early Richmond cherries has shown that the commercial practice of soaking the cherries as soon as picked, for from 4 to 8 hours or overnight in cold water before pitting, helps to plump them and preserve their shape.

Conclusions

Soaking cherries in cold water for several hours before pitting helped to plump them and retain their shape.

Equal weights of sugar and cherries yielded the most desirable cherry preserves from the standpoint of sweetness and consistency and still complied with the government requirement.

The addition to the cherries of one-fourth to one-third of the dry sugar at a time, heating just to boiling, and allowing to stand 2 to 18 hours between additions, helped to retain the shape of the cherries with a minimum of shriveling.

Final temperature of 106-106½° C. (at approximately 900 ft. elevation) gave the best product as regards shrinkage, shriveling, toughness, and texture. Cooking until the final weight was 83 to 85 percent of the total weight at the beginning (83-85% kettle yield) gave more uniform results than cooking to temperature.

The addition of 30 to 40 c.c. of commercial pectin solution or 100 c.c. of homemade apple pectin per 1000 gm. cherries gave a desirable consistency for cherry preserves without producing a jelly.

The addition of small amounts of acid is an improvement to sweet cherries used for preserves (10 c.c. of 4% citric acid per 1000 gm.).

Variety is an important factor in making good cherry preserves. The best results were obtained from those varieties having the larger proportions of pectin and acid (Montmorency, May Duke, English Morello) and relatively small seed.

The addition of some partly ripe cherries improved the consistency somewhat; but less than 25 percent should be used in order to avoid undue toughness of skin and bitterness of flavor.

TABLE 8.—*Effect of Maturity on Cherry Preserves*

Variety of Cherry	25% Unripe 75% Ripe	50% Unripe 50% Ripe	75% Unripe 25% Ripe	100% Unripe	100% Ripe or Standard
arly Richmond	COLOR light red SYRUP less concentrated than standard FLAVOR mild TEXTURE cherries a little tough	COLOR lighter than 25% unripe SYRUP considerably more concentrated than 25% and more than standard FLAVOR good TEXTURE good	COLOR lighter than 50% SYRUP more concentrated than standard FLAVOR good, a little puckery TEXTURE skins a little tough	COLOR faded red SYRUP very good consistency FLAVOR slightly puckery TEXTURE good	COLOR good SYRUP tendency to be thin FLAVOR good TEXTURE good
nglish Morello	COLOR possibly darker than standard SYRUP slightly more concentrated than standard FLAVOR strong TEXTURE skins are a little tougher than standard	COLOR darker than standard SYRUP inclined to jell FLAVOR strong TEXTURE skins are little tougher than standard	COLOR darker than standard SYRUP a little thin FLAVOR strong TEXTURE skins are tougher than standard	COLOR same as standard ripe SYRUP a little thin FLAVOR bitter TEXTURE tough	COLOR dark red SYRUP unusually good consistency FLAVOR slight bitter taste when first made but it disappeared on standing TEXTURE good

BLACKBERRY PRESERVES

The definition of blackberry preserves corresponds to that of cherry preserves, the United States standard applying to both. The ideal also resembles that of cherries; i. e., whole unshriveled fruit in a juice of such consistency that it will not "run" on a plate, nor classify as a jelly.

Since blackberries are less sour than sour cherries, preserves using more than equal weights of sugar were found too sweet. By using a method similar to that for cherries, blackberry preserves were made by heating together, without water, equal weights of washed blackberries and sugar. Temperatures of 104°, 105°, 106°, and 107° C. were tried, with the results shown in Table 9. Judging committees agreed that in the majority of cases a temperature of 105 to 106° C. gave the product most satisfactory in consistency and texture.

Analysis shows that unripe berries contain more pectin than ripe berries. Since consistency depends very largely on pectin content, the effect therefore was tried of using various proportions of unripe berries. Results from the trials with from 25 to 50 percent unripe berries showed no improvement in product. However, the use of 10 percent unripe berries is recommended for preserves to offset any possible overripeness.

TABLE 9.—*Effect of Temperature in Making Blackberry Preserves*

Lot	Items Scored	Temperature			
		104° C.	105° C.	106° C.	107° C.
I	Color	good	good	good	
	Syrup	too thin	good	inclined to jell	
	Flavor	little tart	good	very good	
	Texture	good	good	good	
II	Color	good	good	good	good
	Syrup	good	good	too thick	too thick
	Flavor	good	good	good	good
	Texture	good	good	good	berries little tough
III	Color	good	good	good	good
	Syrup	fair	good	good	too thick
	Flavor	too tart	tart	tart	tart
	Texture	good	good	good	berries tough
IV	Color	good	good	good	good
	Syrup	too thin	good	good	good
	Flavor	tart	slightly tart	good	good
	Texture	good	good	good	berries tough

BLACKBERRY JELLY

Standard for Jelly

The United States Government prescribes for jelly the following standard: "Jelly, fruit jelly, is the clean sound semi-solid gelatinous product made by concentrating to a suitable consistence, the strained juice or the strained water extract from fresh fruit, from cold pack fruit, from canned fruit, or from a mixture of two or all of these with sugar (sucrose)" *(15)*. Such a standard permits considerable latitude in judging "suitable consistence." An ideal as well as a standard becomes necessary. Goldthwaite *(6)* describes the ideal fruit jelly as

"the beautifully colored, transparent, palatable product obtained by so treating fruit juice that the resulting mass will quiver and not flow when removed from its mold; a product with texture so tender that it cuts easily with a spoon and yet so firm that the angles thus produced retain their shape; a clear product that is neither syrupy, gummy, sticky or tough; neither is it brittle; yet it will break, and does this with a distinct, beautiful cleavage which leaves sparkling, characteristic faces. This is that delicious, appetizing substance—a good jelly."

Essential Ingredients for Jelly

To assure such a product, 4 ingredients usually are regarded as necessary—water, acid, pectin, and sugar.

Water. Water is furnished by the blackberries themselves, which contain 80 percent of water, and also by the water used in extracting the juice for jelly. Too large a proportion of water of course results in a solution too dilute for satisfactory jelly; but this is usually described as "too poor in pectin" rather than as "too rich in water".

Acid. Jelly can be made from pectin solutions without acid, if certain salts are present; but McNair *(9)* suggests that this action is really due to the hydrogen-ion present in the salt or on hydrolysis; and Myers and Baker *(8)* emphasize the buffer effect of salts on the weak acids of fruit jellies.

Nelson *(10)* finds in blackberries isocitric, l-malic, and traces of oxalic, succinic, and citric acids. Figures for the percentage of acid necessary for jelly formation are conflicting. Goldthwaite *(5)* reports good jelly from fruits varying from neutral to 0.669 percent acidity (expressed as sulphuric acid); Cruess and McNair *(3)* give the optimum acidity as 0.35 to 1.05 percent (as sulphuric); Singh *(11)*, from 0.035 to 2.835 percent (as sulphuric), depending on the proportion of sugar used, a factor which he regards very important.

Less malic than citric acid seems to be required, and Tarr *(12)* reports tartaric as the most efficient of the common fruit acids. His work also shows that the total acidity of fruit juice used for jelly cannot be correlated with the jellying power, but that the available acid: i. e., the hydrogen-ion concentration, bears a close relation to jellying power. This explains the apparent discrepancy in the figures given above for acidity necessary for jellying, and gives an excellent means of controlling the jellying of fruit juices. For the pectin used in the experimental work of Tarr, pH 3.46 was the minimum hydrogen-ion concentration for jelly formation, and pH 2.9 to 3.0, the maximum.

Figures are not available for hydrogen-ion concentration of the blackberry juice used in the earlier experiments at this Station; but figures were determined in the later work by means of a Youden Quinhydrone Hydrogen electrode apparatus. In all these cases they were found to lie within the range pH 2.97 to pH 3.17, when extractions were made with distilled water, as outlined under "Method of Procedure". These fruit juices are of course not pure pectin solutions as used at the Delaware Station, but jelly stock as used in the ordinary preparation of jelly. To some of the juice having a pH of 3.066, solid tartaric acid was added in varying amounts, yielding juice

of pH 2.715, 2.885, and 2.29. The results of the scores on jellies made from these juices are shown in Table 10. These results show that with juices as acid as pH 2.7 the majority of jellies made (with different proportions of sugar) were fair or better; below this pH few of the jellies were even fair, while at pH 3.066 all scored above 80, —the majority above 90.

Pectin. Pectin is used here in the same sense as in the section on cherry preserves (page 7). From the work of the Delaware Station, the actual amount of pectin, provided it is present at all, seems much less important than the hydrogen-ion concentration, which makes the pectin available for jellying *(12)*. In Table 11 are given analyses of typical lots of blackberries for pectin and pectic acid. The alcohol precipitate test for pectin was checked with these analyses and with the determinations of pH to determine its value to the housewife when other tests are not available. For this test, one teaspoonful of the cooked, cooled fruit juice was put into a shallow cup; to it was added an equal volume of alcohol (denatured alcohol may be used). The two were mixed by gently tipping the cup. If a thick gelatinous mass formed within a few minutes with little or no liquid left, the pectin test was described as "very good"; if slightly more liquid was left, as "good"; if only a few gelatinous lumps formed, as "fair"; and if only a few small flakes, as "poor". This test was used to determine roughly the amount of sugar to be added also and is discussed under sugar.

Sugar. Jelly can be made without added sugar, but the result is sour and tough, is not economical because it requires a large amount of fruit juice, and is neither a standard nor an ideal jelly. The real function of sugar in jellying is not well understood, its use having been largely to improve flavor and texture. McNair *(9)* suggests that dehydration is one possible function, since the point of jelly formation comes when the solution is approximately saturated with sugar. A second function may be that of increasing viscosity—also a factor of importance in determining the jellying point. It has long been known that too little sugar gives a sour, tough jelly, while too much

TABLE 10.—*Results on Jellies of Increasing the Hydrogen-Ion Concentration*

Lot	pH	Pectin Test	Number Scoring		Remarks
			Above 80	Above 90	
28 V-VI 1 and 2	3.066	Good	All	Majority	
3	3.066	Good	Majority	Good proportion	
4	2.715	Good	Majority 17 out of 30	7 out of 30 Scored 70 to 80	6 out of 30
5	2.885	Good	Majority	Majority 13 out of 20	Rest sour, and thin but fairly good jelly texture
7	2.29	Good	8 out of 31	3 out of 31	Majority below 80, most of them below 70

TABLE 11.—*Composition of Blackberries Used*

Sample	Percent Water	Percent Pectin	Percent Pectic Acid	Sugar
1	83.64	0.501	0.307	5.46
2	87.63	0.631	0.259	6.18
3	69.24	0.570	0.312	7.55
4	83.68	0.586	0.328	6.10
*5	69.15	0.840	0.450	1.93

*Unripe Berries

sugar yields a product too sweet to the taste and too soft to form a true jelly. The exact amount to be used has been rather roughly approximated.

The present work was concerned primarily with the development of a practical method for blackberry jelly as a means of utilizing surplus fruit rather than with theoretical considerations in jellying; hence it deals only with the determination of the optimum proportion of sugar to be used under given conditions; and with the selection of a satisfactory end point and the method for its attainment.

Method of Procedure

Extraction

In the juice-extraction process the berries were washed in a spray of water under the faucet, drained, heated to boiling in a covered kettle, then mashed with a wire masher, and simmered, covered, for 10 minutes (or until soft). They were then drained overnight through two thicknesses of cheesecloth, without pressure. The pulp was returned to the kettle with an equal weight of water, simmered for 10 minutes, and drained again through cheesecloth. A third extraction was made in the same manner, the juice from the several extractions being kept separate. Jelly was made from Extraction I, II, and III separately; from I, II, and III combined; from I to II combined; and from II and III combined.

The yield obtained from the various combinations is shown in Figure 1, and, likewise, the consistency of the jellies. It is evident that a second extraction materially increases the yield of jelly from a given amount of fruit and is well worth while from an economic standpoint if the fruit contains abundant pectin. A third extraction increases the yield to a smaller extent and is perhaps not worth while except for fruit very rich in pectin. All extractions yielded good jelly with the proper amount of sugar. For general purposes, combination of Extractions I and II is quite satisfactory; the second extraction yielded a larger amount of juice than did squeezing the bag after the first extraction,—a procedure which is likely to produce cloudy juice.

For most of the experimental work on blackberry jelly at this Station, large amounts of berries were used. Two extractions were made as outlined above, using distilled water. All of the juice was combined, and aliquots of this taken for the individual tests, thus yielding juice of constant composition. The juice was kept in an electric refrigerator at a temperature of 40° F. or below. Since in two weeks' time the pH of the juice, originally 3.066, changed to only 3.13, the juice used for jelly-making, which was kept a much shorter time, was deemed of sufficiently constant composition to show the effects of varying the proportion of sugar and end point.

On some of the extractions, viscosity was determined by an Oswald viscosimeter to determine if time of flow was sufficiently uniform for the development of a simple test of this nature for jellying power. As expected, difficulties were encountered, since the gases contained in the juice produced bubbles which seriously interfered with the flow, while heating to remove these gases increased the concentration. Wide variations were noted. Thus the viscosity of the filtered juice from one lot of berries was 9.959; on standing, stoppered, in the icebox, 10.909 (even when brought to the same temperature for testing); while on filtered juice from another lot in which the berries had been ground it was found to be 27.085. With such wide variations in a standard method of procedure, no information of value could be expected from a simplified test using much cruder equipment. This work therefore was discarded. At the same time it was noted that if berries were picked when some of them still showed red color, the pH was in all cases within the range for jellying given by Tarr *(12)* and yielded good jellies with the proper amount of sugar. For practical use, therefore, the precaution only of picking the berries at this stage need be observed to control the acidity with sufficient accuracy for satisfactory jelly.

Procedure

For most of the work, 300 c.c. portions of juice were used, weighing 306 (305 to 307) gm. This juice was heated to boiling in small aluminum saucepans of uniform size and shape. The weighed amount of sugar was added. Heating was done on a gas hotplate, the pressure being controlled by a water manometer. Boiling to the desired point was carried on as rapidly as possible without boiling over. Temperatures were read on an armored Centigrade thermometer, reading to 0.1 degree, immersed in the jelly to a depth covering the bulb well. Final readings were taken just before the jelly was removed from the fire. Weight of hot saucepan and jelly was taken on a small platform balance. The jelly was poured at once into hot sterile glasses and sealed the next day with melted paraffin. Some weeks later the jellies were opened, tested by means of a jelly strength tester modelled after that described by Tarr *(14)*, and scored by from 3 to 5 judges, using the following score sheet:

Jelly Score Card No. 1

APPEARANCE		20 points
Transparency	5	
Color	5	
Shape	5	
Glistening	5	
TEXTURE		35 points
Tenderness	10	
Quivering	10	
Consistency	10	
Holding angles	5	
FLAVOR		30 points
Naturalness	10	
Sweetness	10	
Strength	10	
KEEPING QUALITIES		15 points

TABLE 12.—*Blackberry Jelly Made with Increasing Proportions of Sugar*

Items Scored	VOLUME OF SUGAR PER CUP OF JUICE								
	¼ cup	½ cup	¾ cup	1 cup	1¼ cups	1½ cups	1¾ cups	2 cups	2¼ cups
1. Color	good	good	good	good	good	good	good		
Flavor	bad	bad	bad	good	good	good	good		
Texture	tough	tough	sl. tough	sl. stiff	sl. stiff	good	tendency to spread		
2. Color	good	good	good	good	good	good	good	good	
Flavor	bad	bad	bad	good	very good	too sweet	too sweet	too sweet	
Texture	tough	tough leathery	tough leathery	tough	very good	good	tendency to spread	spreads	
3. Color	good	good	good	good	good	good	good		
Flavor	bad	bad	fair	very good	ltl. sweet	ltl. sweet	too sweet		
Texture	very tough leathery	very tough leathery	sl. tough leathery	very good	good	good	spreads a little		
4. Color	good	good	good	good	good	good	good		
Flavor	bad	bad	bad	good	very good	too sweet	too sweet		
Texture	tough	tough	sl. tough	sl. tough	very good	good	spreads		
5. Color	good	good	good	good	good	good	good	good	good
Flavor	bad	bad	bad	bad	fair	good	good	too sweet	too sweet
Texture	decidedly tough	decidedly tough	decidedly tough	tough	sl. tough	just ltl. tough	good	tendency to spread	spreads

FIGURE 1.—Consistency and Yield of Jelly from Various Extractions of Ripe Blackberries. Left to right: Extraction 1; Extraction 2; Extraction 3; Extractions 1, 2, and 3; Extractions 1 and 2; Extractions 1 and 3; Extractions 2 and 3

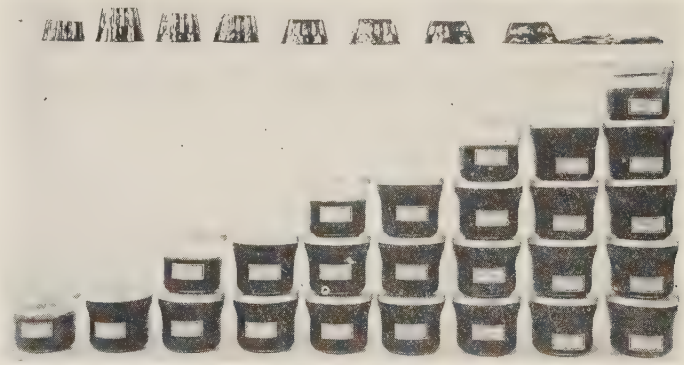


FIGURE 2.—Effect of Increasing Proportions of Sugar on Consistency and Yield of Blackberry Jelly. Left to right: sugar increasing from one-fourth cup per cup of juice to 2¼ cups per cup of juice

With this amount of juice, little difference was found either in the jellies themselves or in the length of time required to form a jelly, whether sugar was added to the cold juice, or after it reached the boiling point. Only three cases of crystallization occurred *(4)*. No record was kept of losses in skimming from the two methods, Goldthwaite reporting greater losses for jellies in which the sugar was added to the cold juice.

Effect of Varying the Proportion of Sugar

In the preliminary experiments with increasing amounts of sugar, two cups of blackberry juice was used for each test. Increasing amounts of sugar were added to different portions, beginning with one-half cup and increasing the amount by ½-cup portions up to 4½ cups, thus giving proportions (by volume) of sugar to juice of ¼:1, ½:1, ¾:1, 1:1, 1¼:1, 1½:1, 1¾:1, 2:1, 2¼:1. The effect on yield and consistency of jelly of increasing the amount of sugar is shown in Figure 2, and the effect on color, flavor, and texture in Table 12. It will be noted that jellies made with the smallest amounts of sugar had a texture very firm and tough, as well as an undesirably sour taste, while those made with the largest amounts of sugar were too soft to hold their shape and had an undesirably sweet taste, thus bearing out the findings for other fruit jellies *(7)*. Between these two extremes, however, was a wide range wherein both texture and flavor were satisfactory.

TABLE 13—*Effect on Score of Jelly of Increasing Amounts of Sugar*

Proportion of Sugar to Juice		
By Volume	By Weight	Average Score*
0.6:1	½:1	84.5
0.9:1	⅝:1	87.7
1.25:1	1:1	91.3
1.5:1	1¼:1	92.2
1.6:1	1⅜:1	96.2
1.8:1	1½:1	88.0

*Only those products are included which formed a true jelly.

In later experiments 1½ cups or 306 gm. of juice was used. Sugar was added by weight as more accurate than volumetric measure. In general, the proportion by volume of sugar to juice was approximately one-fourth more than the proportion by weight.

For blackberry juice a larger proportion of sugar to juice can be used advantageously than is usually recommended for other fruit juices. Thus blackberry jellies made with 1½ to 2 cups of sugar to each cup of juice were good, and those made with 1¼ to 1⅓ cups of sugar per cup of juice were found optimum, whereas for most fruit juices not over one cup of sugar per cup of juice is recommended.

The alcohol test for pectin given above showed some correlation with the amount of sugar that could be added to yield a firm jelly. Thus if this test was "very good" as defined above, good jelly was obtained with 1¼ to 1½ volumes of sugar to each volume of juice, and jellies made with less sugar had a much less desirable texture. If the alcohol test was "good", good jelly was obtained with 1 to 1¼ volumes of sugar per volume of juice. With a "fair" test only ¾ volume of sugar per volume of juice could be used; if "poor", only ½ volume.

Table 13 illustrates how the quality of the jelly, as expressed by the score in percent, improved with increasing amounts of sugar up to a certain point, then declined with further addition of sugar. The figures given are for jellies made from juice at pH 3.066 under identical conditions. They represent the average of from 6 to 12 scores in every case.

Determining when Jelly is Finished

Jelly Test. Three methods were tried for determining when the jellies were finished: 1) the "jellying point" of the household; 2) temperature; and 3) weight of final product. Jelly has long been tested in the household by the first method by dripping it from a spoon and observing the drops. If they "set" into solid drops of jelly along the edge of the spoon instead of running off as a liquid, the jelly is regarded as finished. A silver spoon was found superior to a wooden spoon for this test. With juice of proper pH it was surprising how uniformly this test indicated a jelly which later scored well. The temperature at which this test appeared varied with the amount of sugar used as well as with individual observation, but in all cases it fell between 101° and 103° C.

Temperature. Temperatures of from 101° to 107° C. were tried, readings being taken as described under "Procedure". Above 105° jellies were strong, tough, and stringy. Between 101° and 105° the majority were good. Jellies containing less than one part of sugar by weight to one part of juice did not form a true jelly at 101°. These same jellies at temperatures above 102° to 103° were tough and strong. The larger the amount of sugar, up to 1½ parts by weight, the lower the temperature at which jelly formed. Larger amounts of sugar of course yielded a soft jelly, which on further cooking merely became waxy from concentration of the syrup. With proportions of sugar of 1:1 and 1¼:1 (by weight), temperatures between 101° and 105° gave good jellies; with sugar of 1⅓:1, 101° to 104° was better; and with sugar of 1½:1, 102° gave the best product.

Temperature readings are not difficult to take with a fair degree of accuracy, especially with a Centigrade thermometer reading to 0.1 degree; and thermometers are used by many housewives. Thermometers are an improvement over the "jelly test," since they eliminate the personal factor; but they may be complicated by differences in elevation and, consequently, in boiling point,—a factor often overlooked. The temperatures given are for 900 feet elevation, 102° to 103° C. or 216° to 217° F. giving the best results. Deducting one-half degree C. or one degree F. for each 500 feet elevation above sea level provides a sufficiently accurate correction for blackberry jelly, particularly since on standing the jelly becomes slightly more firm in either case.

Cooking to Weight. To avoid the inaccuracies due to elevation and other barometric changes, and to provide a method for those housewives who do not have thermometers, cooking to weight was tried, with very satisfactory results. Tarr and Baker *(13)* state that jellying occurs when the solution of pectin, represented in this case by fruit extractions, is approximately saturated with respect to sugar —containing between 60 and 70 percent of sugar at 20° C. Such

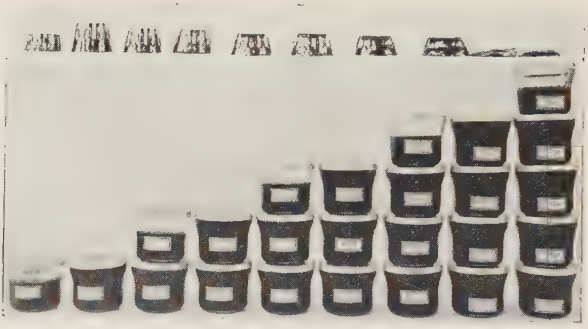


FIGURE 3.—Effect of Increasing Proportions of Sugar on Consistency and Yield of Blackberry Jelly from Unripe Fruit. Left to right: Sugar increasing from one-fourth cup to 2¼ cups per cup of juice

a solution should boil between 103° and 105° C., which is not far from the actual figures as found for good jellies made from jelly stock in the present experiment. Considering the sugar added at the beginning as remaining unchanged in the final product, the percentage of sugar in a jelly can be found by the following formula:

$$\frac{\text{weight of sugar added}}{\text{end weight of jelly}} \times 100 = \text{percentage of sugar in the finished jelly}$$

Similarly, if a satisfactory figure can be established for the percentage of sugar which should obtain in the finished jelly, then this figure can be substituted in the above formula, and the final end weight which the jelly should reach when done can be calculated in advance; thus

$$\frac{\text{weight of sugar added}}{\text{percentage of sugar in the jelly}} \times 100 = \text{end weight that jelly should reach when finished}$$

According to Tarr and Baker *(13)* the figure for percentage of sugar in the finished jelly is 67.6 to 67.9 for pure pectin solutions; and 69 to 72 for stock pectin solutions, the salts in the unpurified pectin apparently producing the difference. In the present work somewhat lower figures were obtained, due perhaps to a difference in standard used to define "jelly," and also to the fact that purified pectin was not used, but simple water extractions of fruit.

In Table 14 are given the mean figures for percentage of sugar in the end weight of all jellies which scored 80 or above and which formed a true jelly, whether the end point used was "jelly test," temperature, or weight. The figures for jelly made with from 1 to

TABLE 14.—*End Weight of Sugar in Jellies*

Proportion of Sugar Added to Juice		Percentage of Sugar in End Weight	
By Weight	By Volume	of Jellies at "Jellying Test"	of all Jellies Scoring above 80
¾:1	0.9:1	52.2	56.
1:1	1¼:1	58.5	62.1
1¼:1	1½:1	66.1	64.0
1⅓:1	1.6:1	60.2	63.4
1½:1	1.8:1	64.5	66.1
Average		60.3	62.7

1½ parts by weight of sugar to 1 of juice—proportions which produced the best products made—range from 62 to 66 percent; the average, close to 63 percent. Since the coefficient of variation for these figures is approximately 6 percent, they may be considered as expressing a relationship that is fairly definite for the conditions given.

It is interesting to note the close relation between these figures and those for percentage of sugar in jellies at the "jelly point," as determined by the spoon test. Thus (Table 14) for jellies made with 1 to 1½ parts by weight of sugar, the percentage of sugar in the final weight of jelly varies from 58.5 to 66 percent, as against 62 to 66 percent for the method of cooking to weight.

FIGURE 4.—Consistency and Yield of Blackberry Jelly Made with the Addition of Various Amounts of Unripe Berries. Left to right: 10, 15, and 25 percent unripe berries added

The percentage of sugar in the end weight of all true jellies at temperatures between 101° and 105° C. is given in Table 15, which again shows agreement with figures obtained by cooking to weight. This is as close as might be expected from simple extractions of fruit.

Very little difficulty is experienced in cooking to a given end weight. At first, frequent weighings may be necessary, but the appearance of the jelly soon becomes a guide to the proper time to begin weighing. If the weights of the kettle plus end weight of jelly to be reached are left on the platform balance, it is a simple matter to weight the jelly once or twice, and reach the desired end weight within a very small error.

Maturity would be expected to affect the jellying power of fruit juice, because both acid and pectin content are greater in unripe than in ripe fruit. Jellies were made from both ripe and unripe berries, the effect of ripeness on yield and texture being shown in Figures 1 and 3. In Figure 4 are shown texture and yield of jellies made with the addition of 10, 15, and 25 percent unripe berries. Greater yield is noted as the percentage of unripe berries increases, since the unripe berries will permit the addition of larger amounts of sugar before becoming too soft to set into jelly; and yield is determined by amount of sugar added.

The effect on flavor, however, of increasing amounts of unripe berries will limit their use. The use of from one-tenth to one-fourth of partly ripe blackberries (not green) did not affect flavor unfavorably. Over-ripe berries, being low in acid, would give a pH outside the range for jellying, and therefore would not yield good jelly. The recommendation that each lot of berries contain some berries still

showing red gave lots of berries with a range in pH from 2.97 to 3.17, all of which yielded good jellies.

A jelly strength tester modeled along the lines of that described by Tarr *(14)* was used for testing blackberry jellies as they were scored, with the aim of developing a test that would be more reliable than scoring, in which personal opinion plays a large part. Pressure was developed by water running into a siphon bottle from a larger bottle above it. Testing was begun always with water at the same level in the siphon bottle, and the pressure in the siphon was standardized at the beginning, as suggested by Tarr.

Jellies were tested after paraffining, thereby introducing a large source of error,—but one to which jellies submitted for laboratory test would also be subject. Tests were made soon after the jelly was made and again, several months later, on duplicates.

TABLE 15.—*Correlation of Temperature with Percentage of Sugar in End Weight*

Temperature	Average Percentage of Sugar*
101	57.5
102	57.8
103	61.5
104	64.8
105	66.1
Average	61.5

*6 to 10 trials in each case.

In general, the jelly strength test became higher as the end temperature was increased, and lower after the sugar content was increased to a certain point. More than one-half of the good jellies tested fell between 20 and 40 on the jelly-strength tester, but the remainder showed wide variations on both top and bottom tests. Some of these variations undoubtedly were due to differences in temperature of paraffin as well as to variations in the tester itself. The results were no more accurate in placing a jelly than those based on scoring; and the test consumed considerably more time.

Conclusions

Blackberries picked while still showing some red color gave extractions having a pH between 2.97 and 3.17; all made true jelly.

Good blackberry jelly was made with 1¼ to 1½ volumes of sugar per volume of juice; the best was made with 1¼ to 1⅓ volumes of sugar.

The alcohol test for pectin gave some indication of the amount of sugar which may be added to a given juice for firm jelly.

Temperatures between 102° and 103° C. or 216° and 217° F. gave the best jellies at 900 feet elevation. Temperatures as high as 105° C. were satisfactory when the proportion of sugar was optimum.

Cooking jelly to weight, previously determined, in order to yield jelly containing a definite percentage of sugar when finished, offers several advantages over other methods of determining when jelly is finished. The figures giving the best results for all proportions of sugar were 62 to 66 percent.

Addition of some unripe berries increases the yield of jelly but should be limited to 10 to 25 percent of the berries to avoid changes in flavor.

Bulletin 235 June, 1930

Pasture Experiments

by T. E. ODLAND, C. V. WILSON,
H. O. HENDERSON, and E. P. DEATRICK

A Pasture Which Could Be Much Improved by Means of Liming and Top-dressing with Fertilizer

UNIVERSITY OF
LIBRARY

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

SUMMARY AND CONCLUSIONS

Pasture improvement experiments were conducted on the Live Stock and the Dairy farms of the West Virginia Agricultural Experiment Station situated near Morgantown. The soil is typical in its topography of much pasture land in the state. The land was considered too steep for reestablishing the pasture by plowing. The only cultivation given was disking on some of the plots.

Top dressings of manure alone, manure and superphosphate, superphosphate alone, and nitrate of soda alone were applied both in combination with and without lime. Three different seed mixtures were compared. The value of cultivating with a disk harrow was tested. A number of plots were left without treatment to serve as checks.

Each plot was divided into a grazed and an ungrazed half. Yields were obtained on the ungrazed half and estimates on the percentage of various classes of pasture plants and weeds were made on both the grazed and ungrazed half of each plot every year.

A combination of manure and superphosphate, together with lime, produced the best results on both farms. A seed mixture was used with this treatment, and the plots were disked. This combination produced the highest yields, and the greatest improvement was noted in the kinds of pasture grasses thriving on such plots. Without lime the treatment was not nearly as effective as with lime.

Manure and lime proved to be the treatment next best to the combination of manure, superphosphate, and lime in effectiveness of improving the pasture. Without lime the response was much less.

Superphosphate with lime produced a decided increase in yield and quality. Superphosphate alone without lime was much less effective.

When lime was applied alone without any fertilizer treatment only small increases in yield resulted. The quality of pasture was, however, improved considerably by the treatment.

An application of nitrate of soda together with lime resulted in some increase in yield, but not as great as lime with superphosphate alone. Without lime the nitrate had little effect on either the yield or quality of the pasture.

Very little difference was observed between the 3 seed mixtures used, either in quantity of grass produced or quality of the pasture sod.

An application of superphosphate and lime without seeding or disking increased the yields and improved the quality of the pasture sod. The better pasture plants developed, and the weeds and poorer grasses decreased.

Disking alone without other treatments had very little effect on pasture.

Seeding alone without other treatment was of no value.

The cattle showed a very marked preference for certain plots where improved pasture grasses were increasing.

As a result of these experiments it is recommended that pastures of this type be top dressed with lime and superphosphate. In most cases a simple seed mixture probably should be added and the land, if not too rough, may be disked or harrowed. If manure is available a top dressing of this may also be expected to net a good return when applied to such pastures. When in doubt as to the advisability of using either lime or fertilizer on a pasture, a small area of the pasture should be used for a preliminary trial. The treatment of the remainder of the pasture should be based on this test.

Pasture Experiments

by T. E. ODLAND, C. V. WILSON,
H. O. HENDERSON, and E. P. DEATRICK*†

THE PASTURE crop in West Virginia is the most important crop in the state and at the same time the one on which the least study has been made. A number of pasture demonstrations have been carried on in different parts of the state but until recently there have been few attempts to get an actual measure of the increase in quantity and quality of pasture grasses resulting from various treatments. The reason for such meager information in this state as well as in most other states lies largely in the difficulties involved in conducting pasture investigations.

If the experiments include grazing and the measurement of increase in either meat or milk production, it is desirable to have several animals on each plot, and large plots are, therefore, required. If a number of treatments are compared on such plots, the area becomes large and the cost is likely to be prohibitive.

Another method employed in pasture investigations is to use plots similar to those used in field experiments. Instead of grazing the plots, the yields and values of the treatments are determined by cutting and weighing the grass. Although this method is the more convenient of the two, it is subject to the objection that the conditions of the experiment are not the same as they would have been under actual grazing.

In the experiments described in this bulletin an attempt was made to combine the two methods by grazing one-half of each plot, and cutting the other half for the yield determinations. Although it was not possible to make yield determinations on the grazed parts of the plots, a comparison was made each year by estimating the percentage of the various plants on the grazed and ungrazed halves of each plot.

A pasture survey[1] of 245 farms in West Virginia made a few years ago showed that on the average it required approximately four acres to carry a cow through the pasture season and a little more for a 3-year-old steer. It was estimated that a properly managed pasture in the area should support an animal on every two acres. The survey indicated that the pastures were not as productive

*The authors wish to acknowledge the assistance given by H. K. Rowley and D. R. Dodd of the Agronomy Department staff in making the flora estimates and to F. D. Cornell, Jr., of the Farm Economics staff for making the graphs and plan of the experiments.

†Mr. Odland resigned February, 1929.

[1]W. Va. Agri. Exp. Sta. Bul. 177.

as they had been some years ago and were becoming less productive. The farmers interviewed were all of the opinion that the pastures were rapidly deteriorating, but little agreement was evident as to the best remedy or the chief causes for the poor condition. A previous experiment at this Station[2], in which sheep were used to measure the value of different treatments, indicated that little improvement may be expected from an application of lime alone, but that lime in combination with either superphosphate or complete fertilizer results in marked improvement.

Recent experiments by the Pennsylvania Station[3] showed the greatest growth of bluegrass where complete fertilizer and lime were applied, and their use appeared to be profitable. The calculated return from an acre in good bluegrass pasture exceeded that from an acre of the crops of a regular 4-year rotation. Experiments at Cornell University[4] indicate that the greatest need of pastures in that state is lime and superphosphate.

TYPES OF PASTURE

Pastures may generally be classed as temporary, rotation, or permanent. In a temporary pasture, land is sown to some crop or combination of crops to provide a supplementary pasture for part of the season. In a rotation pasture, land in a regular rotation of crops is seeded and used for pasture for from one to several years. A permanent pasture is used for pasture for a greater number of years without plowing or reseeding. Permanent pastures may be grouped into 3 classes as to methods for treatment: (1) those that can be plowed and then re-established; (2) those too steep or rough to make plowing and reseeding practical but which may be improved by top-dressing with fertilizer and lime; and (3) those on poor, hilly lands more suitable for timber production than pasture.

The experiments of the Pennsylvania Station indicate that the best method of improving pastures of the first class is to plow, lime, and fertilize them, just as would be done with land for any other crop in a regular rotation. The largest proportion of pasture land in West Virginia probably belongs to the second class, land that is too steep and rolling to make plowing and reseeding practical. The experiments reported in this bulletin were conducted on land of this type.

PLAN OF THE EXPERIMENTS

The pasture experiments described in this bulletin were planned to obtain further information on the improvement of permanent pastures of the type that is too steep to plow. Because of the limited land available it was necessary to select treatments that would answer the more important questions relating to pasture improvement.

[2]W. Va. Agr. Exp. Sta. Bul. 177.
[3]Penna. Agr. Exp. Sta. Bul. 195.
[4]Cornell University Memoir 104.

Two series of plots were provided. One series consisting of 44 tenth-acre plots was laid out in 1922 on the Live Stock farm of the University near Morgantown. The other series, a duplicate of the first, was located about a half-mile away on the Dairy farm, and was begun in 1923. Both areas are rather steep and typical of much of the pasture land in the state. The pasture on the Dairy farm was in a little better state of fertility, as shown by the yields of grass obtained. The soil on both farms is classified as Dekalb clay loam. Acidity tests showed a lime requirement of about two tons of limestone per acre.

FIGURE 1.—Pastures like this should not be plowed, because of danger of soil erosion. They can often be much improved without plowing

The treatments consisted of manure, manure and superphosphate, superphosphate, and nitrate of soda. A limed strip extended across all plots so that for each treatment there was a limed half as well as an unlimed half. In addition to the fertilizer and lime treatments 3 seed mixtures were compared, and disking was contrasted to no-cultivation.

As shown in Figures 2 and 3, each experiment consisted of 4 series of plots, each 33 by 132 feet. Each treatment was replicated 3 times. Two plots in each series were left untreated for checks. The yield reported in each case is the average of the 4 plots for each year. Four-foot alleys separated the plots and a 16-foot roadway separated the various series. A strip 4 rods wide was limed* lengthwise through the middle of each series and across all the plots. Thus

*The lime used in this experiment was furnished by the Security Cement and Lime Co., now the North American Cement Corporation, Hagerstown, Md.

half of each plot was limed and half was not limed. A fence extended through the middle of each series so that half of each plot could be kept ungrazed. The yields were obtained by cutting the grass on the ungrazed halves.

The fertilizing materials were applied at the following rates per acre: manure, 8 tons, superphosphate, 300 pounds, and nitrate of soda, 100 pounds. Hydrated lime was applied at the rate of 1½ tons per acre—the equivalent of two tons of ground limestone. The fertilizers and manure were to be applied every third year, and the lime treatments every sixth year. The initial superphosphate and lime treatments were applied on the Live Stock farm in the fall of 1922, the manure during the following winter, and the nitrate of soda the following spring. The initial treatments on the Dairy farm were made in the fall of 1923 and spring of 1924. A second application of manure and fertilizer was made on the Live Stock farm in the spring of 1926 and on the Dairy farm in the spring of 1927. Yields are for 6 years on the Live Stock farm plots and for 5 years on the Dairy farm plots.

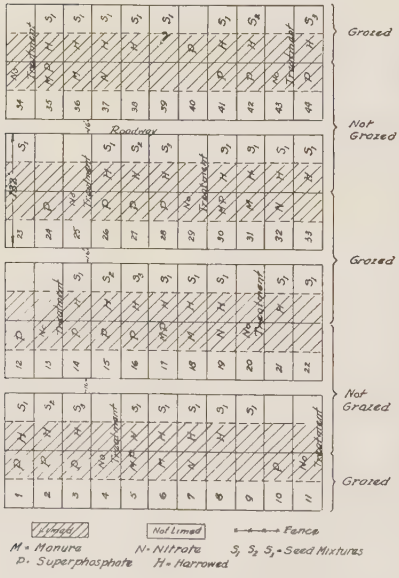


FIGURE 2.—Plan of pasture plots on the Live Stock farm. Each plot is 132 feet long and 33 feet wide. A 4-foot alley separates adjoining plots

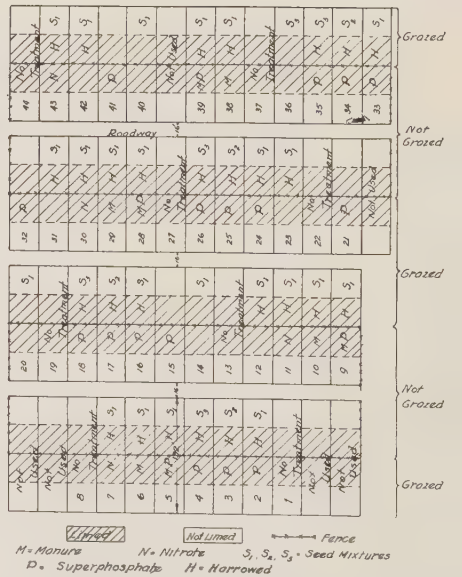


FIGURE 3.—Plan of pasture plots on the Dairy farm. Plots are 33x132 feet with a 4-foot alley separating adjoining plots

Seed Mixtures and Applications per Acre

Three different seed mixtures were sown. Seed mixture No. 1 was used as the standard on a number of plots subjected to various treatments. Mixtures No. 2 and 3 were sown separately on a plot in each series for comparison with Mixture No. 1. The following mixtures were used:

Seed Mixture No. 1

Timothy	4 lbs. per acre
Kentucky bluegrass	8 lbs. per acre
Alsike clover	3 lbs. per acre
White clover	1 lb. per acre

Seed Mixture No. 2

Timothy	4 lbs. per acre
Kentucky bluegrass	8 lbs. per acre
Orchard grass	4 lbs. per acre
Red clover	5 lbs. per acre
White clover	1 lb. per acre

Seed Mixture No. 3

Timothy	4 lbs. per acre
Kentucky bluegrass	4 lbs. per acre
Canada bluegrass	4 lbs. per acre
Orchard grass	2 lbs. per acre
Red top	2 lbs. per acre
Meadow fescue	2 lbs. per acre
Tall oat grass	4 lbs. per acre
Alsike clover	2 lbs. per acre
Sweet clvoer	3 lbs. per acre
White clover	1 lb. per acre
Japan clover	3 lbs. per acre

Mixture No. 2 differs from mixture No. 1 in that medium red clover is substituted for alsike, and orchard grass is added. Mixture No. 3 contained seven species of grasses and four of clovers in order that the degree of their establishment could be determined. The seed mixtures were applied soon after the initial lime and fertilizer applications. The plots so designated in the plan were harrowed once with a disk harrow after seeding. The timothy and alsike or timothy and medium-red clover in the mixtures were employed to produce a growth while the Kentucky bluegrass and white clover were becoming established.

The ungrazed half of the plots was cut with a mowing machine twice a year and the yields were obtained by weight. A small sample was taken for moisture determination at the time of weighing in the field. The dry weights given in the tables were computed from the field weights by using the moisture determinations of these samples. To determine the equivalent value of yields in hay of average moisture content, the yields as given should be increased by about 15 percent.

In order to study the effect of the treatments on the different varieties of plants, an area one yard square was staked off in the center of each quarter of a plot. There was thus a square in the limed and unlimed parts of the grazed and ungrazed halves of each plot. At the beginning of each experiment, and in each succeeding year at approximately the same time of season, a careful estimate was made of the percentage of each kind of grass and other plants which made up the growth on each of these square yard areas.

TABLE 1.—*Yields in Pounds per Acre (Dry Weight) from Pasture Plots Located on the Live Stock Farm in 1923 to 1928*

Fertilizer Treatment	Lime Treatment	Seed Mixture No.	Culture	Yield in Pounds per Acre (Dry Weight)						Average 1923-28
				1923	1924	1925	1926	1927	1928	
Manure and Superphosphate..	Limed	1	Harrow	532	2673	962	1579	1442	1531	1453
Manure and Superphosphate..	Not Limed ...	1	Harrow	307	1083	449	930	1066	1013	808
Manure	Limed	1	Harrow	500	1742	848	1335	1389	1395	1201
Manure	Not Limed ...	1	Harrow	287	853	357	705	965	997	694
Superphosphate..	Limed	1	Harrow	465	1703	743	1146	1222	1353	1105
Superphosphate..	Not Limed ...	1	Harrow	302	1185	497	777	948	1013	787
Superphosphate..	Limed	2	Harrow	550	1720	692	1097	1076	1189	1054
Superphosphate..	Not Limed ...	2	Harrow	300	950	497	804	899	864	719
Superphosphate..	Limed	3	Harrow	508	1750	809	1159	1121	1438	1131
Superphosphate..	Not Limed ...	3	Harrow	332	1302	656	955	1163	1209	936
Superphosphate..	Limed	0	None	494	1051	582	1110	1194	1386	969
Superphosphate..	Not Limed ...	0	None	306	823	420	630	790	868	639
Nitrate of soda...	Limed	1	Harrow	423	1154	646	1172	1042	1120	926
Nitrate of soda...	Not Limed ...	1	Harrow	254	637	394	737	710	687	570
No fertilizer	Limed	1	Harrow	385	1134	647	836	971	1027	833
No fertilizer	Not Limed ...	1	Harrow	259	870	426	574	858	780	628
No fertilizer	Limed	1	None	403	1056	541	889	943	901	789
No fertilizer	Not Limed ...	1	None	245	547	322	376	575	574	440
No fertilizer	Limed	0	None	429	879	482	826	856	968	740
No fertilizer	Not Limed ...	0	None	251	654	339	447	669	652	502

FIGURE 4. — Average yields 1923-28 in pounds per acre (dry weight) from pasture plots located on the Live Stock farm

Classification of Pasture Plants

The plants occurring on the plots were grouped into 3 classes. In the first group, designated as "native grasses," were included poverty grass (*Danthonia spicata*), brome sedge (*Andropogon furcatus*), sedges, and similar grasses or grass-like plants of little value as pasture plants. Poverty grass made up by far the largest proportion of all native grasses, especially on the Live Stock farm, where at the beginning of the experiment many plots were almost entirely covered by it.

The second group was designated as "pasture grasses and legumes." This included bluegrass, red-top, the clovers, and other pasture grasses and legumes of recognized economic importance. At the end of the 1928 season the pasture grasses in the better plots consisted almost entirely of Kentucky bluegrass and white clover. The third group, designated as "weed," embraced all plants not included in the first two classes. The percentage of the square yard area which was bare of plants also was estimated.

The condition found in the staked square yard may be taken as representative of the quarter of the plot on which it was located. Although certain irregularities occurred in these readings, it was felt that they gave a fairly trustworthy criterion of what changes were taking place in the vegetation under the different treatments.

Experimental Results Obtained on the Live Stock Farm

The yields obtained on the Live Stock farm with the various treatments used are indicated in Table 1, which shows that the most marked pasture improvement resulted from an application of lime and 8 tons of manure per acre, reinforced with 300 pounds of superphosphate. The average yield for the 6-year period was 1,453 pounds per acre as compared with 1,201 pounds where manure and lime were used without superphosphate. These plots were harrowed, and Seed mixture No. 1 was used. On the unlimed parts the yields were 808 and 694 pounds per acre respectively. This contrast shows very strikingly the necessity of liming as well as fertilizing. The yields for the various treatments are shown in Figure 4.

Superphosphate alone was used on 4 series of plots both with and without liming. On 3 series of plots 3 grass mixtures were used, while on the fourth no seed was applied. Seed mixture No. 1 was used on the superphosphate plot, the manure-superphosphate plot, the manure plot, and the nitrate plot, all of which were disked and otherwise treated alike for comparative purposes. On the limed half of the superphosphate plot the yield was 1,105 pounds per acre, or a little less than on the plot receiving manure and lime. On the unlimed half the superphosphate plot yielded 787 pounds as compared with 694 pounds for the manured plot. From these results it would seem that, under the conditions of the experiment, superphosphate is as effective as manure, or as manure and phosphate when lime is not added, and nearly as effective as manure when lime is added.

Comparison of Seed Mixtures

When the 3 seed mixtures on the limed part of the superphosphate plots are compared it is seen that Mixture No. 3 yielded an average of 1,131 pounds per acre; Mixture No. 1, 1,105 pounds; and Mixture No. 2, 1,054 pounds. Although Mixture No. 3, the one with the 11 different kinds of seeds, yielded a little more than the other two mixtures, the difference is not large enough to be significant. On the unlimed halves of these superphosphate plots, Mixture No. 3 yielded 936 pounds per acre; Mixture No. 1, 787 pounds; and Mixture No. 2, 719 pounds. More difference in favor of Mixture No. 3 appears here than on the limed halves.

FIGURE 5.—Effect of manure, superphosphate, and lime on pasture plots on the Live Stock farm in 1924. The plot on the left of A—B had no fertilizer applied, while the one on the right received manure and superphosphate. The half of each plot next to the fence and below the division line C—D was limed, while above the line no lime was applied. Note the heavy growth of clover on the limed half of the plot receiving manure and superphosphate

If the yields of the superphosphate plots where seed mixtures were used are compared with unseeded superphosphate plots, it is found that where no seed was used the average yield was 969 pounds on the limed half and 639 pounds on the unlimed half. With Mixture No. 2, the lowest yielding of the 3 mixtures, the yields were 1,054 and 719 pounds respectively on the limed and unlimed halves. This seed mixture yielded only small returns. In many cases pasture grasses and legumes will come in when the proper lime and fertilizer treatments are made. There was some Kentucky bluegrass and white clover on these plots at the beginning of the experiment. When lime and superphosphate were applied these pasture plants were enabled to make good growth and replace some of the undesirable weeds and grasses.

On the plots where no fertilizer or seed was applied the yields were 740 pounds on the limed half, and 502 pounds on the unlimed

half. This indicates that lime alone, although effecting some improvement in the pasture, is not sufficient. The average yield for a superphosphate application alone was 639 pounds per acre. Apparently, if either treatment were to be used alone on this type of pasture, the lime treatment should be chosen. Th combination of lime and superphosphate, however, is the most effective and the most economical.

An application of 100 pounds of nitrate of soda resulted in a yield of 926 pounds on the limed half of the plot, and 570 pounds on the unlimed half, or 137 pounds more on the limed part, and 130 pounds more on the unlimed part, than on the plots where no fertilizer was used. Although the nitrate application was effective in producing some improvement it was not as efficient as manure or superphosphate under the conditions of the experiment.

Effect of Various Treatments on Growth of Pasture Grasses

In considering the yields per acre due to these various treatments it is necessary also to take into consideration the kinds of grasses growing on these plots. Some of the plots bearing the most marked improvement, as recorded for the last year of the experiment, yielded as high as 80 percent tame grasses, consisting chiefly of Kentucky bluegrass, whereas some of the poorer plots yielded less than ten percent of tame grasses. Kentucky bluegrass is worth many times more, pound for pound, than such grasses as Danthonia and brome sedge. Thus the actual value of a treatment is not indicated by the increase in yield only.

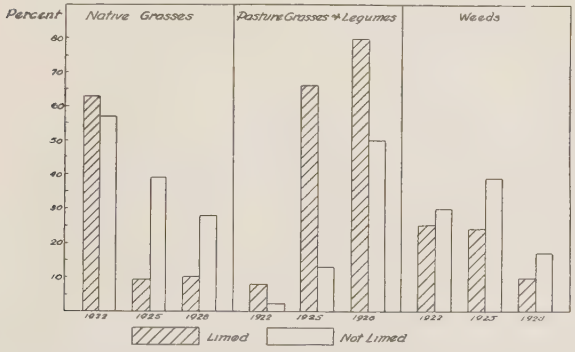


FIGURE 6.—Percentage of native grasses, pasture grasses and legumes, and weeds on the limed and unlimed halves of pasture plots on the Live Stock farm in 1922, 1925, and 1928. Not grazed. Fertilizer treatment: manure and superphosphate

The amounts of the various kinds of grasses and weeds on the plots receiving the treatments are estimated by individual years in Tables 13 and 14 (see pages 16 and 17). Table 2 presents a summary of the figures for the Live Stock farm, including an average of the yields from all superphosphate treatments, as well as of the yields from all untreated plots. Differences between these plots were not considered large enough to warrant separate figures in this summary table. For convenience the grazed and ungrazed parts of the same plot are shown in adjoining columns.

TABLE 2.—*Percentage of Native Grasses, Pasture Grasses, Weeds, and Vacant Space on Grazed and Ungrazed Plots on the Live Stock Farm in* 1922, 1925, *and* 1928

Fertilizer Treatment	Grazing	Percent of Various Plants and Vacant Space											
		Native Grasses			Pasture Grasses and Legumes			Weeds			Vacant		
		1922	1925	1928	1922	1925	1928	1922	1925	1928	1922	1925	1928
LIMED													
Manure and superphosphate	Grazed	49	24	9	8	54	84	33	19	7	10	3	0
Manure and superphosphate	Not grazed	63	9	10	8	66	80	25	24	10	4	1	0
Manure	Grazed	40	35	15	22	42	76	31	21	9	7	2	0
Manure	Not grazed	51	18	10	18	52	77	29	30	13	2	0	0
Superphosphate	Grazed	51	40	38	12	39	51	31	19	8	5	3	2
Superphosphate	Not grazed	42	20	37	22	61	51	30	18	9	6	1	2
Nitrate of soda	Grazed	34	36	57	26	36	34	36	26	9	4	2	0
Nitrate of soda	Not grazed	41	30	63	30	39	20	23	30	16	6	1	1
No fertilizer	Grazed	46	50	55	23	29	31	27	19	10	4	2	3
No fertilizer	Not grazed	58	41	65	12	30	20	24	29	13	5	2	2
NOT LIMED													
Manure and superphosphate	Grazed	45	41	24	18	26	66	30	31	10	7	2	0
Manure and superphosphate	Not grazed	57	39	28	2	13	50	30	39	17	11	9	5
Manure	Grazed	51	43	28	15	26	62	29	29	10	5	2	0
Manure	Not grazed	53	31	44	8	14	40	32	52	16	7	3	0
Superphosphate	Grazed	51	51	53	9	14	32	33	33	13	6	3	2
Superphosphate	Not grazed	44	43	56	14	21	22	36	35	19	6	1	3
Nitrate of soda	Grazed	55	62	80	18	11	7	24	24	12	3	3	1
Nitrate of soda	Not grazed	54	55	79	13	6	2	26	35	14	7	4	5
No fertilizer	Grazed	45	57	60	19	31	24	31	24	15	5	2	1
No fertilizer	Not grazed	56	60	74	10	4	3	28	31	18	5	5	5

Table 2 also shows a very marked improvement in the kind of plants found in the pasture in the case of some of the treatments. Where manure, superphosphate, and lime were applied the native grasses decreased on the grazed half from 49 percent in 1922 to 9 percent in 1928, the pasture grasses and legumes increased from 8 to 84 percent, and weeds decreased from 33 to 7 percent. Vacant space decreased from 10 percent in 1922 to none in 1928.

On the ungrazed halves the decrease in native grasses and weeds and the increase in pasture grasses and legumes corresponded to that on the grazed halves. This treatment therefore approximately trebled the yield as compared with the untreated plots. Furthermore, the material harvested consisted of highly nutritious grasses and clovers, while in the untreated plots the material harvested had a very low nutritive value. The relative percentages of the various plants on the ungrazed half of the manure and superphosphate plots are shown in Figure 6.

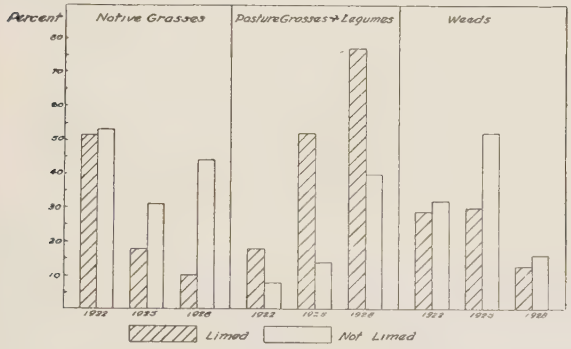


FIGURE 7. — Percentage of native grasses, pasture grasses and legumes, and weeds on the limed and unlimed halves of pasture plots on the Live Stock farm in 1922, 1925, and 1928. Not grazed. Fertilizer treatment: manure

On the unlimed part of these plots there is also a decrease of native grasses and an increase in pasture grasses, but the improvement is not as marked as where lime also was applied.

Where manure alone was applied with lime the native grasses decreased from 40 to 15 percent on the grazed half and from 51 to 10 percent on the ungrazed half. The pasture grasses and legumes increased from 22 to 76 percent on the grazed half and from 18 to 77 percent on the ungrazed half. Here again we see a very marked increase in the better pasture grasses where manure and lime were applied. The relative percentages for the manured plots on the ungrazed half are shown in Figure 7.

The unlimed part of these plots, like those where manure and superphosphate were applied, shows less improvement than where lime was applied.

An application of superphosphate with and without various seed mixtures resulted in a decrease of native grasses of from 51 to 38 percent on the grazed half and from 42 to 37 percent on the ungrazed half. The pasture grasses were increased from 12 and 22 percent respectively in 1922 to 51 percent in 1928 on the grazed and ungrazed

halves. The amount of weeds also was decreased. The results are shown for the ungrazed half in Figure 8.

On the unlimed half little change was noted in the percentage of native grasses, but some increase was noticed in the amount of pasture grasses and legumes. The application of 100 pounds of nitrate of soda once in 3 years did not materially decrease the native grasses nor increase the percentage of pasture grasses and legumes. As a matter of fact, in 1928 the average estimated percentage of native grasses was greater than in 1922. There was some increase in improved grasses on the limed portion, but not enough to be considered of much value. The results are shown in Figure 9.

TABLE 3.—*Average Yields per Acre (Dry Weight) and Percentage of Native and Pasture Grasses in* 1928 *on Pasture Plots on Live Stock Farm in* 1923 *to* 1928

Fertilizer Treatment	Lime Treatment	Average Yield in Pounds per Acre (Dry Weight)	Percent in 1928	
			Native Grasses	Pasture Grasses and Legumes
Manure and Superphosphate	Limed	1453	10	80
Manure and Superphosphate	Not limed	808	28	50
Manure	Limed	1201	10	77
Manure	Not limed	694	44	40
Superphosphate	Limed	1065	37	51
Superphosphate	Not limed	770	56	22
Nitrate of soda	Limed	926	63	20
Nitrate of soda	Not limed	570	79	2
No fertilizer	Limed	775	65	20
No fertilizer	Not limed	518	74	3

On the plots where no fertilizer was applied the results, expressed in terms of the percentage of the various kinds of grasses and weeds, are similar to results where nitrate was applied. Lime alone produced little change in the percentage of native grasses and yielded only a relatively small increase in the percentage of tame grasses. The results obtained are shown in Figure 10.

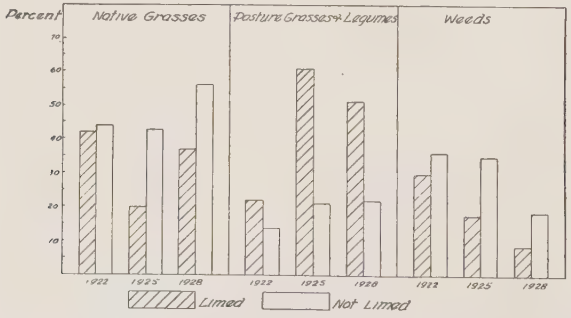


FIGURE 8. — Percentage of native grasses, pasture grasses and legumes, and weeds on the limed and unlimed halves of pasture plots on the Live Stock farm in 1922, 1925, and 1928. Not grazed. Fertilizer treatment: superphosphate

In Table 3 the average yields of the ungrazed halves of the plots are presented together with the estimated stands of native and pasture grasses. The same grouping of plots has been used as for Table 2. Table 3 shows that the range of yields extends from an average of 518 pounds per acre, with no treatment, to 1,453 pounds

per acre where manure, acid phosphate, and lime were applied. In the first case only 3 percent of the vegetation was made up of improved pasture grasses and legumes, while in the other case 80 percent was in improved pasture grasses and legumes. The plots bearing a high percentage of pasture grasses and legumes consisted almost entirely of Kentucky bluegrass and white clover in the last two years of the experiment. Medium-red and alsike clover were very prominent on the limed halves of the fertilized plots the first two years. After that these clovers rapidly disappeared, and bluegrass and white clover took their place. Only a few scattering plants of alsike or medium-red clover were found on the unlimed portion of any of the plots at any time.

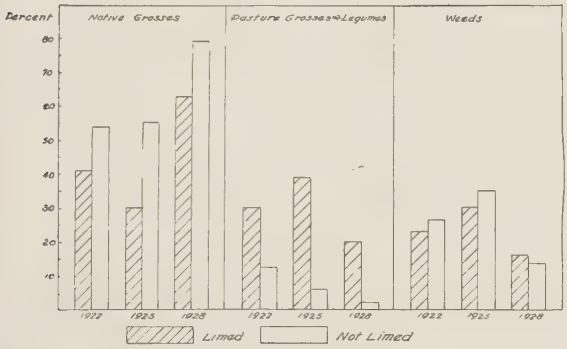


FIGURE 9. — Percentage of native grasses, pasture grasses and legumes, and weeds on the limed and unlimed halves of pasture plots on the Live Stock farm in 1922, 1925, and 1928. Not grazed. Fertilizer treatment: nitrate of soda

Effect of Seeding

Table 1 shows that little difference in yield resulted from the various mixtures used. Table 13 also indicates that the various mixtures had little effect upon the percentage of the various kinds of plants.

Where Mixture No. 1 was used the alsike clover made a very vigorous growth on the limed parts of the fertilized plots during the first two years. Practically no alsike plants were found outside the limed areas. The timothy also was quite generally in evidence on the limed and treated plots. During the last two years Kentucky bluegrass and white clover were the predominant plants on the limed and fertilized areas. The seed application, where the plots were neither limed nor fertilized, gave no improvement in the composition of the grasses.

The results obtained with Mixture No. 2, in which orchard grass was added and red clover was substituted for alsike, were very similar to those obtained with Mixture No. 1. The clover was very much in evidence on the limed and fertilized plots the first two years. After that it gave way to Kentucky bluegrass and white clover. The orchard grass, only a small part of the total crop in any year, appeared early in the spring. There was more of it than any of the other seeded grasses on the unlimed parts of the different plots.

TABLE 13.—*Estimated Percentage of Native Grasses, Pasture Grasses and Legumes, Weeds, and Vacant Space on Grazed and Ungrazed Halves of Pasture Plots on the Live Stock Farm, 1922 to 1928*

Fertilizer Treatment	Lime Treatment	Seed Mixture No.	Culture	Estimated Percent Stand																										
				Native Grasses							Pasture Grasses and Legumes							Weeds							Vacant						
				1922	1923	1924	1925	1926	1927	1928	1922	1923	1924	1925	1926	1927	1928	1922	1923	1924	1925	1926	1927	1928	1922	1923	1924	1925	1926	1927	1928
GRAZED																														
Manure and superphosphate ..	Limed	1	H	49	50	22	24	11	22	9	8	18	58	54	74	66	84	33	25	18	19	11	10	7	10	7	2	3	4	2	0
Manure and superphosphate ..	Not limed	1	H	45	45	40	41	32	29	24	18	32	30	26	49	62	66	30	19	26	31	16	8	10	7	4	4	2	3	1	0
Manure	Limed	1	H	40	32	32	35	19	14	15	22	35	45	42	66	74	76	31	28	22	21	13	11	9	7	5	1	2	2	1	0
Manure	Not limed	1	H	51	47	44	43	46	28	28	15	25	30	26	34	55	62	29	19	20	29	17	15	10	5	9	6	2	3	2	0
Superphosphate..	Limed	1	H	59	46	33	34	41	29	37	9	26	47	50	48	56	53	27	23	18	12	8	12	8	5	5	2	4	3	3	2
Superphosphate..	Not limed	1	H	54	53	45	61	67	53	56	2	8	18	5	8	28	26	37	31	31	30	20	15	15	7	8	6	4	5	4	3
Superphosphate..	Limed	2	H	47	35	29	51	51	27	39	13	20	34	24	31	58	51	33	36	33	23	12	11	8	7	9	4	2	6	4	2
Superphosphate..	Not limed	2	H	58	53	54	56	69	62	54	13	22	11	10	10	23	34	24	17	30	32	18	14	11	5	8	5	2	3	1	1
Superphosphate..	Limed	3	H	49	45	13	21	24	21	34	26	29	66	52	59	68	56	21	22	20	23	14	10	9	4	4	1	4	3	1	1
Superphosphate..	Not limed	3	H	51	46	29	33	40	48	45	22	26	46	34	31	35	43	22	21	22	31	23	14	12	5	7	3	2	6	3	0
Superphosphate..	Limed	0	None	50	50	45	52	36	44	43	2	13	32	29	48	38	45	42	34	21	17	12	14	8	6	3	2	2	4	4	4
Superphosphate..	Not limed	0	None	43	54	45	52	59	66	58	1	1	3	5	6	9	24	48	39	47	38	26	20	14	8	6	5	5	9	5	4
Nitrate of soda ..	Limed	1	H	24	31	38	36	36	60	57	26	27	21	36	46	20	34	36	34	38	26	13	19	9	4	8	3	2	5	1	0
Nitrate of soda ..	Not limed	1	H	55	54	54	62	69	78	80	18	16	18	11	11	10	7	24	24	25	24	16	11	12	3	6	3	3	4	1	1
None	Limed	1	H	30	32	40	37	30	32	41	39	39	28	39	49	43	48	27	26	31	23	16	19	10	4	3	1	1	5	6	1
None	Not limed	1	H	44	47	38	51	64	62	63	15	13	10	12	10	8	22	38	34	50	36	21	26	15	3	6	2	1	5	4	0
None	Limed	1	None	44	51	46	50	56	49	55	17	14	25	29	25	29	26	35	30	26	19	12	13	14	4	5	3	2	7	9	5
None	Not limed	1	None	45	47	52	53	59	68	65	18	19	15	22	12	14	19	30	29	31	24	20	14	14	7	5	2	1	9	4	2
None	Limed	0	None	55	57	53	57	61	61	63	17	18	24	23	21	24	24	24	21	20	17	14	12	9	4	4	3	3	4	3	4
None	Not limed	0	None	45	53	54	63	62	62	56	23	17	13	16	20	20	28	28	23	27	18	14	15	15	4	7	6	3	4	3	1
NOT GRAZED																														
Manure and superphosphate ..	Limed	1	H	63	42	13	9	3	4	10	8	16	65	66	86	84	80	25	33	21	24	10	12	10	4	9	1	1	1	0	0
Manure and superphosphate ..	Not limed	1	H	57	56	35	39	21	20	28	2	6	24	13	52	57	50	30	29	34	39	20	18	17	11	9	7	9	7	5	5
Manure	Limed	1	H	51	47	36	18	10	6	10	18	19	37	52	75	74	77	29	29	25	30	15	20	13	2	5	2	0	0	0	0
Manure	Not limed	1	H	53	45	37	31	29	41	44	8	13	27	14	43	35	40	32	31	32	52	25	23	16	7	11	4	3	3	1	0
Superphosphate..	Limed	1	H	41	41	15	16	23	21	38	21	29	66	69	65	69	49	30	26	15	14	11	9	11	8	4	4	1	1	1	2
Superphosphate..	Not limed	1	H	39	46	31	22	43	41	56	15	5	27	28	15	31	21	41	43	41	48	41	28	20	5	6	1	2	1	0	3
Superphosphate..	Limed	2	H	40	42	22	34	17	24	34	25	28	56	54	68	59	50	28	25	21	11	14	15	11	7	5	1	1	1	2	5
Superphosphate..	Not limed	2	H	47	45	38	49	67	58	65	7	11	31	22	7	15	15	40	36	29	28	23	21	13	6	8	2	1	3	6	7
Superphosphate..	Limed	3	H	40	37	16	13	23	25	41	24	30	62	71	65	63	48	31	27	21	16	11	10	9	5	6	1	0	1	2	2
Superphosphate..	Not limed	3	H	38	37	21	42	46	50	48	18	21	49	26	26	28	29	36	35	28	31	25	21	22	8	7	2	1	3	1	1
Superphosphate..	Limed	0	None	49	53	28	19	25	44	35	17	18	47	49	48	36	58	30	26	24	30	24	20	7	4	3	1	2	3	0	0
Superphosphate..	Not limed	0	None	54	61	55	57	59	54	56	13	12	18	10	22	24	22	28	25	25	33	17	20	20	5	2	2	0	2	2	2
Nitrate of soda ..	Limed	1	H	41	44	38	30	50	51	63	30	21	40	39	32	25	20	23	28	20	30	15	21	16	6	7	2	1	3	3	1
Nitrate of soda ..	Not limed	1	H	54	56	51	55	63	68	79	13	5	9	6	4	1	2	26	34	36	35	26	21	14	7	5	4	4	7	10	5
None	Limed	1	H	51	60	34	39	50	47	65	23	16	44	35	34	30	21	22	19	20	22	14	20	13	4	5	2	4	2	3	1
None	Not limed	1	H	54	62	57	58	66	59	69	17	12	9	8	6	9	4	24	21	29	30	24	26	21	5	5	5	4	4	6	6
None	Limed	1	None	65	62	42	38	60	59	69	9	15	38	32	20	18	16	22	22	19	28	19	21	12	4	1	1	2	1	2	3
None	Not limed	1	None	69	64	70	69	73	74	77	5	5	6	3	2	3	2	18	21	17	23	16	15	15	8	10	7	5	9	8	6
None	Limed	0	None	59	59	54	44	56	62	63	8	13	25	21	19	17	23	27	25	19	33	23	17	12	6	3	2	2	2	4	2
None	Not limed	0	None	51	57	59	56	66	65	75	9	6	3	3	4	8	3	36	31	34	36	24	22	18	4	6	4	5	6	5	4

TABLE 14.—*Estimated Percentage of Native Grasses, Pasture Grasses and Legumes, Weeds, and Vacant Space on Pasture Plots on the Dairy Farm, 1923 to 1928*

Fertilizer Treatment	Lime Treatment	Seed Mixture No.	Culture	Estimated Percent Stand																							
				Native Grasses						Pasture Grasses and Legumes						Weeds						Vacant					
				1923	1924	1925	1926	1927	1928	1923	1924	1925	1926	1927	1928	1923	1924	1925	1926	1927	1928	1923	1924	1925	1926	1927	1928
GRAZED																											
Manure and superphosphate ..	Limed	1	H	34	28	14	9	12	5	10	36	63	70	74	87	51	34	22	19	14	8	5	2	1	2	0	0
Manure and superphosphate ..	Not limed	1	H	34	27	27	34	34	36	26	43	35	44	55	53	34	28	36	20	11	11	6	2	2	2	0	0
Manure	Limed	1	H	49	24	20	14	21	9	3	46	45	61	63	81	41	30	34	23	15	10	7	0	1	2	1	0
Manure	Not limed	1	H	42	33	28	29	26	34	14	18	36	30	55	55	39	45	34	36	18	11	5	4	2	5	1	0
Superphosphate..	Limed	1	H	27	22	16	19	24	12	10	37	52	52	63	81	52	36	29	23	9	6	11	5	3	6	4	1
Superphosphate..	Not limed	1	H	40	22	28	34	54	56	13	20	28	30	27	31	41	52	41	31	18	12	6	6	3	5	1	1
Superphosphate..	Limed	2	H	46	28	18	17	26	24	9	31	60	55	64	66	41	35	20	23	9	8	4	6	2	5	1	2
Superphosphate..	Not limed	2	H	28	28	26	36	36	26	9	28	21	25	31	39	54	40	52	34	30	31	9	4	1	5	3	4
Superphosphate..	Limed	3	H	37	21	10	18	16	14	6	44	64	65	70	75	50	32	25	15	10	9	7	3	1	2	4	2
Superphosphate..	Not limed	3	H	12	6	21	18	27	19	24	24	30	32	37	42	59	67	48	46	34	36	5	3	1	4	2	3
Superphosphate..	Limed	0	None	30	32	22	21	22	16	3	24	48	51	54	73	59	34	29	25	20	11	8	10	1	3	4	0
Superphosphate..	Not limed	0	None	42	33	43	46	50	64	3	8	6	6	10	16	50	56	50	44	36	16	5	3	1	4	4	4
Nitrate of soda ..	Limed	1	H	46	33	40	34	36	48	2	17	16	22	49	36	47	46	41	38	12	15	5	4	3	6	3	1
Nitrate of soda ..	Not limed	1	H	55	45	34	36	39	52	5	14	14	14	23	21	35	37	48	43	34	26	5	4	4	7	4	1
None	Limed	1	H	42	37	36	24	35	37	1	16	28	38	40	46	46	39	32	30	18	12	11	8	4	8	7	5
None	Not limed	1	H	18	36	36	50	66	69	2	17	3	4	8	10	70	41	59	41	25	21	10	6	2	5	1	0
None	Limed	1	None	50	35	30	39	36	39	5	25	38	26	39	46	39	36	26	26	14	8	6	4	6	9	11	7
None	Not limed	1	None	33	23	23	37	37	46	0	7	3	3	4	6	60	67	73	57	54	45	7	3	1	3	5	3
None	Limed	0	None	44	35	33	34	34	28	4	16	24	32	47	56	46	43	41	30	15	13	6	6	2	4	4	3
None	Not limed	0	None	35	34	39	37	53	55	14	17	14	17	21	22	44	42	42	40	21	18	7	7	5	6	5	5
NOT GRAZED																											
Manure and superphosphate ..	Limed	1	H	33	22	7	11	17	9	17	48	56	61	71	84	47	30	36	25	12	7	3	0	1	3	0	0
Manure and superphosphate ..	Not limed	1	H	45	34	38	50	57	54	12	30	32	26	29	37	36	33	30	21	14	9	7	3	0	3	0	0
Manure	Limed	1	H	46	41	11	16	11	16	3	21	55	57	75	70	42	37	34	26	13	13	9	1	0	1	1	1
Manure	Not limed	1	H	39	31	21	36	54	46	6	29	44	36	35	40	49	39	34	28	11	14	6	1	1	0	0	0
Superphosphate..	Limed	1	H	32	36	14	20	25	19	11	27	50	52	56	69	51	36	36	28	18	12	6	1	0	0	1	0
Superphosphate..	Not limed	1	H	39	32	30	51	75	75	9	12	15	14	6	14	44	52	51	33	16	11	8	4	4	2	3	0
Superphosphate..	Limed	2	H	41	30	6	21	13	22	11	45	71	54	75	69	39	22	23	22	12	9	9	3	0	3	0	0
Superphosphate..	Not limed	2	H	35	32	26	53	70	76	8	22	24	10	7	9	49	39	49	32	20	14	8	7	1	5	3	1
Superphosphate..	Limed	3	H	31	37	9	13	40	23	6	29	54	48	45	67	51	32	37	35	14	9	12	2	0	4	1	1
Superphosphate..	Not limed	3	H	40	27	34	39	48	64	8	22	20	24	36	21	46	50	45	34	15	14	6	1	1	3	1	1
Superphosphate..	Limed	0	None	32	36	13	21	26	19	3	36	54	48	59	72	58	28	32	30	14	9	7	0	1	1	1	0
Superphosphate..	Not limed	0	None	43	42	33	50	72	65	4	14	20	13	9	23	48	44	47	36	18	11	5	0	0	1	1	1
Nitrate of soda ..	Limed	1	H	47	29	20	40	49	44	5	30	56	34	39	43	44	39	24	24	11	11	4	2	0	2	1	2
Nitrate of soda ..	Not limed	1	H	41	36	33	56	62	74	5	8	10	6	8	6	50	52	56	34	28	16	4	4	1	4	2	4
None	Limed	1	H	44	37	30	42	61	58	8	26	37	34	25	31	39	33	31	21	13	10	9	4	2	3	1	1
None	Not limed	1	H	44	30	46	60	80	84	7	8	8	6	4	5	43	56	44	30	15	10	6	6	2	4	1	1
None	Limed	1	None	24	33	24	39	62	45	4	15	34	24	10	28	62	51	42	36	28	26	10	1	0	1	0	1
None	Not limed	1	None	42	41	48	46	70	78	3	4	3	3	1	3	49	50	44	42	24	15	6	5	5	9	5	4
None	Limed	0	None	34	34	25	36	45	45	10	22	34	26	35	44	50	42	40	37	20	11	6	2	1	1	0	0
None	Not limed	0	None	44	51	59	66	80	75	4	8	6	5	4	13	44	40	34	27	15	11	8	1	1	2	1	1

Because of its early appearance in the spring and its ability to thrive on poor soils it appears to be desirable for a pasture mixture.

The complex mixture designated as No. 3 did not produce any prominent plants not included in Mixtures 1 and 2. Sweet clover sown in this mixture did not produce very many plants even on the limed and fertilized plots. To obtain a good stand of sweet clover

TABLE 4.—*Average Yields per Acre on Seeded and Unseeded Pasture Plots on the Live Stock Farm in* 1923 *to* 1928

Fertilizer Treatment	Lime Treatment	Average Yields 1923-28	
		Seeded	Not Seeded
Superphosphate	Limed	1097	969
Superphosphate	Not limed	814	639
No fertilizer	Limed	811	740
No fertilizer	Not limed	534	502

the land probably should have been disked several times, and much more seed used. No very good stands of Japan clover were obtained on any of the plots; at the end of the experiment there were practically no plants of this legume. Later experiments conducted on the Agronomy farm indicate that Korean lespedeza is much more likely to reseed itself under the conditions of the present experiment than the common Japan clover which was used. Meadow fescue and tall oat grass did not become established to any extent in any of the plots. They were found on both the limed and unlimed parts of the plots, but more thickly on the limed parts. Red top and Canada bluegrass were found quite generally on the plots bearing this mixture—more thickly on the limed portion of the plots.

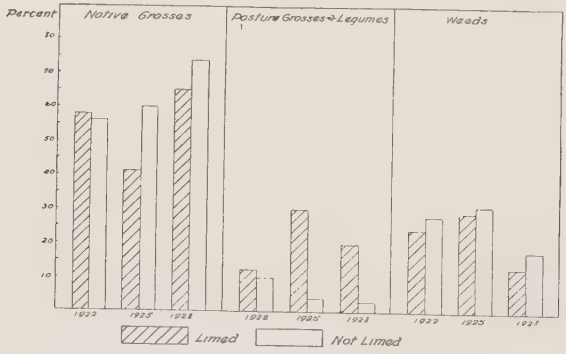


FIGURE 10.—Percentage of native grasses, pasture grasses and legumes, and weeds on the limed and unlimed halves of pasture plots on the Live Stock farm in 1922, 1925, and 1928. Not grazed. Fertilizer treatment: none

In Table 4 the yields of the seeded plots are compared with the yields of unseeded plots. Comparisons are made between plots receiving the same treatments, with the exception of the seeding. Table 4 shows that, where seed was applied together with superphosphate, the average yield was 1,097 pounds per acre, while on the unseeded plots the average yield was 969 pounds. On the unlimed part the yields were 814 and 639 pounds, respectively. Some increase was

obtained from seeding, but the increase was not large, whether or not lime was used. Table 13 also indicates that at the end of the experiment there was as high a percentage of pasture grasses and legumes in the unseeded as in the seeded plots. Apparently there were enough plants of bluegrass present in these plots at the beginning of the experiment to develop and form a good pasture sod when the proper fertilizer and lime treatments were made.

TABLE 5.—*Average Yields per Acre on Cultivated and Uncultivated Pasture Plots on the Live Stock Farm in* 1923 *to* 1928

Fertilizer Treatment	Lime Treatment	Average Yields 1923-28	
		Cultivated	Not cultivated
No fertilizer	Limed	833	789
No fertilizer	Not limed	628	440

On the unfertilized plots the average yield on the limed half was 811 pounds per acre when seeded, and 740 pounds when not seeded. On the unlimed halves the yields were 534 and 502 pounds on the seeded and unseeded plots, respectively. The difference is so small as to be of no significance in either case. To reseed a pasture of this type with any kind of mixture without applying both lime and some kind of fertilizer is to waste time and effort.

Effect of Cultivation

A comparison between a series of plots disked after seeding and a series where the seed was applied without subsequent disking is also afforded by this experiment. The only plots where this comparison can be made, however, are those where no fertilizer was applied. This perhaps is not a fair test for cultivation but it was the best that could be devised with the area available. The results are shown in Table 5. On the limed half the cultivated part yielded 833 pounds per acre, and the uncultivated half, 789 pounds. The yields on the unlimed parts were 628 and 440 pounds respectively.

TABLE 6.—*Average Yields per Acre for the Years* 1923 *to* 1928 *and Grand Average Yield on the Seeded Pasture Plots on the Live Stock Farm, Where Phosphate Was Used with and without an Application of Lime*

Fertilizer Treatment	Lime Treatment	Yields in Pounds per Acre						Average 1923-28
		1923	1924	1925	1926	1927	1928	
Superphosphate..	Limed	508	1724	748	1134	1140	1329	1097
Superphosphate..	Not limed	311	1146	550	845	1003	1029	814

Although cultivation resulted in a small increase in yields, it was so small that it seems safe to state that one may well afford to lime and fertilize a pasture of this type even if it is not possible to go over it with a disk or springtooth harrow. The most important factors are lime and fertilizer. The Virginia Station[5] also found very little benefit from cultural treatments of bluegrass pastures.

[5]Virginia Agr. Exp. Sta. Bul. No. 204.

Yearly Variation in Pasture Yields

Table 6 represents a combination of all seeded superphosphate plots, to show the yearly variation in yields. The lowest yields were obtained in 1923, a rather dry year, with weather unfavorable for the growth of pasture grasses. The following year (1924), characterized by a cold, late spring with much rain, showed a yield of more than 3 times that of the first year. The clovers produced their maximum yield in 1924. The following year showed a sharp decrease in yield, followed in succeeding years by a gradual increase, due largely to the gradual increase in the amount of Kentucky bluegrass.

Grazing vs. Mowing a Pasture

That grazing has a different effect upon pasture grasses and other plants in general than cutting for hay is usually accepted. This experiment was planned so that it might be possible to study the comparative influence of grazing and of cutting the grass twice a year. The comparison was made by careful estimate each year of the percentage of the various classes of plants on the square yard area, staked off on both the grazed and ungrazed halves of each plot. The results obtained as given in Table 13 show (see page 00), as far as could be determined, little difference in the character of the vegetation between the grazed and the ungrazed parts. The results are shown in Figures 11 to 15. It would seem from this that cutting the plots twice a year and weighing the cut material gives a fairly accurate measure of what might be expected from various treatments under actual pasturing conditions, if the kinds of grasses making up the harvested material are also taken into consideration.

On the grazed half of the plots a very marked difference could be noted in the preference of the cattle for certain plots. Where the better pasture grasses predominated the plots were much more closely grazed than where weeds and native grasses made up the bulk. The boundary of certain plots could easily be traced in many instances from the difference in amount of grazing.

EXPERIMENTAL RESULTS OBTAINED ON THE DAIRY FARM

The yields obtained with the various treatments on the Dairy Farm are shown in Table 7. As was the case on the Live Stock Farm, the application of a combination of manure and superphosphate together with lime resulted in the most marked improvement in the pasture. The average yield for this combination during the 5-year period was 2,388 pounds per acre. Not only was the yield the greatest, but the percentage of pasture grasses and legumes was higher on these plots than under any other treatment. This is shown in the accompanying tables and graphs. Where manure only was applied with lime the average yield was 2,027 pounds per acre, or about 300 pounds per acre less than where superphosphate was added to the manure. On the unlimed parts the yields were 1,787 and 1,753

TABLE 7. — *Yields in Pounds per Acre (Dry Weight) from Pasture Plots Located on the Dairy Farm in 1924 to 1928*

Fertilizer Treatment	Lime Treatment	Seed Mixture No.	Culture	Yield in Pounds per Acre (Dry Weight)					Averages 1924-28
				1924	1925	1926	1927	1928	
Manure and superphosphate	Limed	1	Harrow	2549	1933	1484	2947	3026	2388
Manure and superphosphate	Not limed	1	Harrow	1861	1012	908	2463	2691	1787
Manure	Limed	1	Harrow	2380	1401	1064	2525	2764	2027
Manure	Not limed	1	Harrow	2128	978	881	2233	2544	1753
Superphosphate	Limed	1	Harrow	1825	1327	1152	1904	2391	1720
Superphosphate	Not limed	1	Harrow	1193	569	447	1271	1579	1012
Superphosphate	Limed	2	Harrow	1918	2894	1316	1829	2155	2022
Superphosphate	Not limed	2	Harrow	1126	854	588	1272	1542	1076
Superphosphate	Limed	3	Harrow	1869	1354	1098	1830	2204	1671
Superphosphate	Not limed	3	Harrow	1154	596	587	1319	1576	1046
Superphosphate	Limed	0	None	1677	1106	1066	1784	2151	1557
Superphosphate	Not limed	0	None	1094	525	566	1388	1582	1031
Nitrate of soda	Limed	1	Harrow	1579	839	907	1938	1717	1396
Nitrate of soda	Not limed	1	Harrow	1194	464	473	1457	1377	993
No fertilizer	Limed	1	Harrow	1384	865	841	1430	1847	1273
No fertilizer	Not limed	1	Harrow	912	346	507	1125	1441	866
No fertilizer	Limed	1	None	1072	602	673	1262	1377	997
No fertilizer	Not limed	1	None	853	344	445	986	1037	733
No fertilizer	Limed	0	None	1287	775	741	1462	1819	1217
No fertilizer	Not limed	0	None	1088	439	509	1203	1317	911

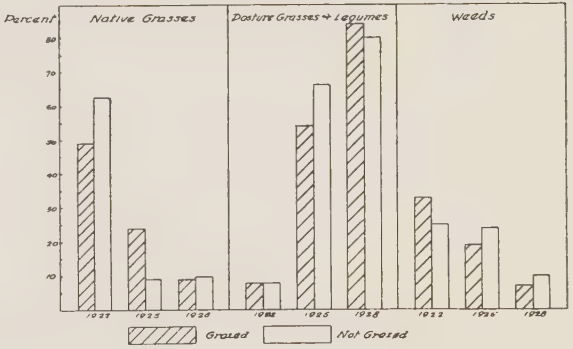


FIGURE 11. — Percentage of native grasses, pasture grasses and legumes, and weeds on the grazed and ungrazed halves of pasture plots on the Live Stock farm in 1922, 1925, and 1928. Limed. Fertilizer treatment: manure and superphosphate

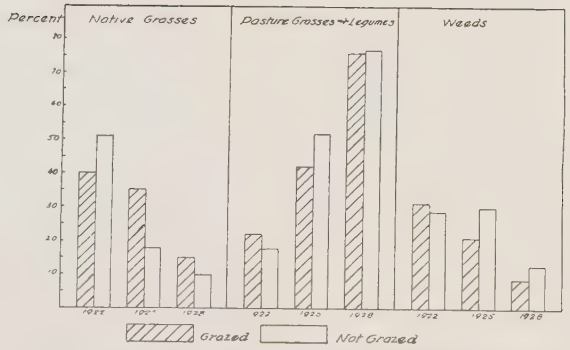


FIGURE 12.—Percentage of native grasses, pasture grasses and legumes, and weeds on the grazed and ungrazed halves of pasture plots on the Live Stock farm in 1922, 1925, and 1928. Limed. Fertilizer treatment: manure

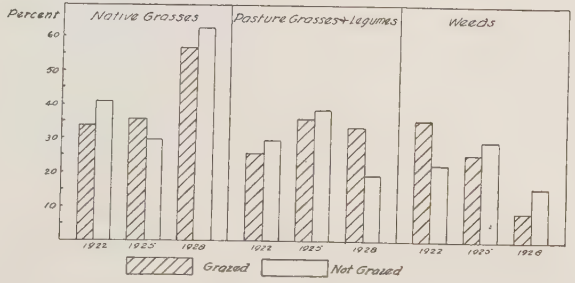


FIGURE 14.—Percentage of native grasses, pasture grasses and legumes, and weeds on the grazed and ungrazed halves of pasture plots on the Live Stock farm in 1922, 1925, and 1928. Limed. Fertilizer treatment: nitrate of soda

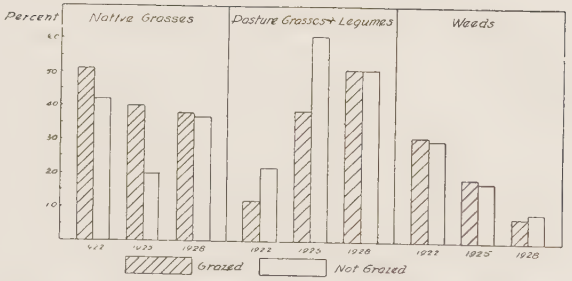


FIGURE 13.—Percentage of native grasses, pasture grasses and legumes, and weeds on the grazed and ungrazed halves of pasture plots on the Live Stock farm in 1922, 1925, and 1928. Limed. Fertilizer treatment: superphosphate

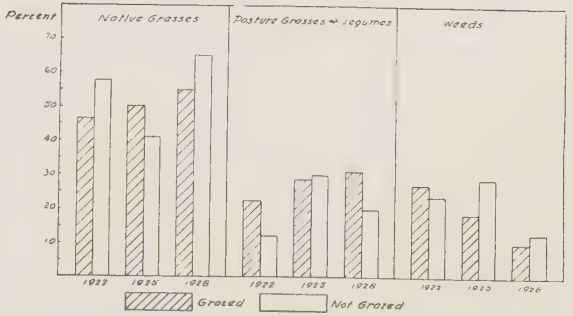


FIGURE 15.—Percentage of native grasses, pasture grasses and legumes, and weeds on the grazed and ungrazed halves of pasture plots on the Live Stock farm in 1922, 1925, and 1928. Limed. Fertilizer treatment: none

pounds per acre for the manure-and-superphosphate and the manure-alone plots, respectively. Without the lime the addition of phosphate to the manure apparently had no appreciable effect on yield.

The average yields on the Dairy farm were considerably higher than those on the Live Stock farm, where the soil apparently was in a lower state of fertility. This probably accounts for some of the cases wherein the response to certain of the treatments was not the same on the two farms. In general, however, the results on the two farms agree very closely.

On the 3 series of plots where the 3 different grass mixtures were used the yields on the limed half were 1,720 pounds with Mixture No. 1, 2,022 pounds with Mixture No. 2, and 1,671 pounds with Mixture No. 3, On the unlimed halves the yields were 1,012, 1,076, and 1,046 pounds per acre for the same respective mixtures. Mixture No. 2 produced the highest average yield for the 5-year period, due chiefly to the heavy crop of red clover on these plots in 1925. The season was exceptionally favorable for red clover, and high yields were obtained. If this one year were omitted the average yields for all 3 mixtures would be very nearly the same. On the unlimed parts the average yields are approximately the same for all mixtures. Except for the one season, therefore, there was little difference in yields with the various mixtures either on the limed or unlimed parts of the plots on the Dairy Farm. This agrees with results obtained on the Live Stock farm. A simple mixture therefore is to be preferred over a more complicated and expensive one.

The series of plots where superphosphate alone and Seed Mixture No. 1 were used can be compared with the series where manure only was applied, since these two series are alike except for fertilizer treatment. The manure alone with lime yieled an average of 2,027 pounds per acre, while superphosphate alone with lime yielded 1,720 pounds. On the unlimed parts the yields were 1,753 and 1,012 pounds, respectively, for the manure and superphosphate plots. On these plots, therefore, manure alone, whether used with or without lime, was more effective than superphosphate in increasing the yields of pasture grasses.

When the series of plots where superphosphate was added, but no seed applied, is compared with the plots where both seed and superphosphate were applied, a small increase in yield is seen on the limed part when seed is applied, but no significant difference is noted where no lime was used. Where no seed was used the yields were 1,557 pounds and 1,031 pounds on the limed and unlimed parts, respectively. With Seed Mixture No. 1 the average yields were 1,720 pounds on the limed half and 1,012 pounds on the unlimed half. As on the Live Stock farm, some bluegrass and other pasture grasses were present when the experiment was started, and where the right fertilizer treatment was applied together with lime, these grasses developed and a good sod was formed even though no seed was applied.

TABLE 8.—*Percentage of Native Grasses, Pasture Grasses, Weeds, and Vacant Space on Grazed and Ungrazed Plots on the Dairy Farm in* 1923, 1925, *and* 1928

Fertilizer Treatment	Grazing	Percent of Various Plants and Vacant Space											
		Native Grasses			Pasture Grasses and Legumes			Weeds			Vacant		
		1923	1925	1928	1923	1925	1928	1923	1925	1928	1923	1925	1928
LIMED													
Manure and superphosphate	Grazed	34	14	5	10	63	87	51	22	8	5	1	0
Manure and superphosphate	Not grazed	33	7	9	17	56	84	47	36	7	3	1	0
Manure	Grazed	49	20	9	3	45	81	41	34	10	7	1	0
Manure	Not grazed	46	11	16	3	55	70	42	34	13	9	0	1
Superphosphate	Grazed	35	16	17	7	56	74	50	26	8	8	2	1
Superphosphate	Not grazed	34	10	21	8	57	69	50	32	10	8	0	0
Nitrate of soda	Grazed	46	40	48	2	16	36	47	41	15	5	3	1
Nitrate of soda	Not grazed	47	20	44	5	56	43	44	24	11	4	0	2
No fertilizer	Grazed	45	33	33	3	31	51	44	35	11	7	4	5
No fertilizer	Not grazed	26	26	48	8	35	37	50	38	16	8	1	1
NOT LIMED													
Manure and superphosphate	Grazed	34	27	36	26	35	53	34	36	11	6	2	0
Manure and superphosphate	Not grazed	45	38	54	12	32	37	36	30	9	7	0	0
Manure	Grazed	42	28	34	14	36	55	39	34	11	5	2	0
Manure	Not grazed	39	21	46	6	44	40	49	34	14	6	1	0
Superphosphate	Grazed	30	30	41	12	21	41	51	48	24	6	1	3
Superphosphate	Not grazed	39	31	70	7	20	17	47	48	12	7	1	1
Nitrate of soda	Grazed	55	34	52	5	14	21	35	48	26	5	4	1
Nitrate of soda	Not grazed	41	33	74	5	10	6	50	56	16	4	1	4
No fertilizer	Grazed	30	36	56	7	9	15	54	56	25	8	2	3
No fertilizer	Not grazed	44	53	78	4	6	9	44	39	12	7	2	2

The application of 100 pounds of nitrate of soda every third year together with seed produced an average yield of 1,396 pounds on the limed half and 993 pounds on the unlimed half. This shows some increase over the plots receiving no fertilizer, but less than where superphosphate was used. As would be expected, the greatest improvement from the use of nitrate resulted in the year the application was made. If nitrate of soda is used for top dressing it probably should be applied every spring for best results.

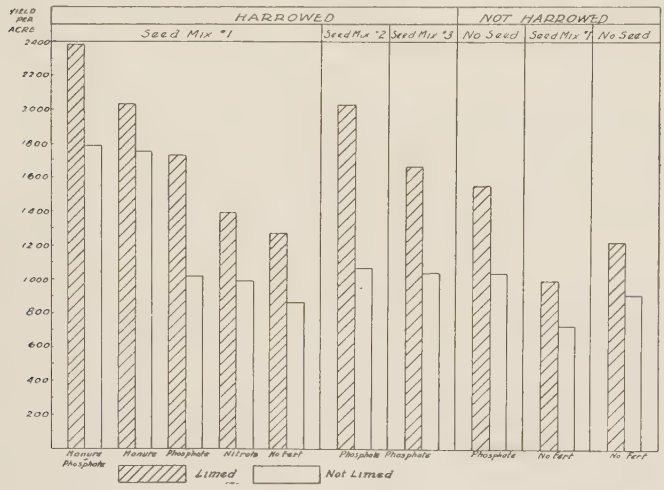


FIGURE 16.—Average yield 1924-28 in pounds per acre (dry weight) from pasture plots located on the Dairy farm

The plots which received no fertilizer, seed, or cultural treatments yielded an average of 1,217 pounds per acre where lime was applied and 911 pounds where no lime was used. As on the Live Stock farm, the use of lime alone resulted in considerable improvement in the pasture, but the best results were obtained when both lime and fertilizer were applied.

The average yields of the various treatments are shown in Figure 16.

Effect of Various Treatments on Growth of Different Pasture Grasses

The percentages of the various kinds of grasses and weeds for each year and for the various treatments are estimated in Table 14 (See page 00). Table 8 presents a summary of Table 14. The plots are grouped as in the summary table for the Live Stock farm.

Results on the Dairy farm were very similar to those obtained on the Live Stock farm. The stand on the former contained a slightly higher percentage of pasture grasses and legumes at the conclusion of the experiment. The greatest improvement in the pasture plants was made where lime, superphosphate, and manure were applied. On the grazed half of the plot the native grasses decreased from 34 percent in 1923 to 5 percent in 1928, and the pasture grasses and legumes increased from 10 percent in 1923 to 87 percent in 1928. The pasture grasses and legumes referred to consisted almost en-

tirely of Kentucky bluegrass and white clover at the end of the experiment in 1928. The native grass consisted chiefly of poverty grass (*Danthonia spicata*).

TABLE 9.—*Average Yields per Acre (Dry Weight) of Pasture Plots on the Dairy Farm in 1924 to 1928 and Percentage of Native and Pasture Grasses in 1928*

Fertilizer Treatment	Lime Treatment	Average Yield in Pounds per Acre (Dry Weight)	Percent in 1928	
			Native Grasses	Pasture Grasses and Legumes
Manure and Superphosphate	Limed	2388	9	84
Manure and Superphosphate	Not limed	1787	54	37
Manure	Limed	2027	16	70
Manure	Not limed	1753	46	40
Superphosphate	Limed	1742	21	69
Superphosphate	Not limed	1041	70	17
Nitrate of soda	Limed	1396	44	43
Nitrate of soda	Not limed	993	74	6
No fertilizer	Limed	1176	48	37
No fertilizer	Not limed	855	78	9

The effect of the manure and superphosphate treatments on the various classes of pasture plants is shown in Figure 17.

On the unlimed halves the increase in improved grasses and legumes was much less than on the limed parts, and no decrease was noted in the amount of native grasses.

The plot receiving manure alone produced the next greatest increase in the amount of pasture grasses and legumes, and decrease in native grasses and in weeds. The stand of pasture grasses and legumes increased from an average of 3 percent in 1923 to 81 percent on the grazed half in 1928 and to 70 percent on the ungrazed half. The stand of native grasses decreased from 49 to 46 percent on the grazed and ungrazed halves in 1923 to 9 and 16 percent, respectively, in 1928. These results are shown in Figure 18.

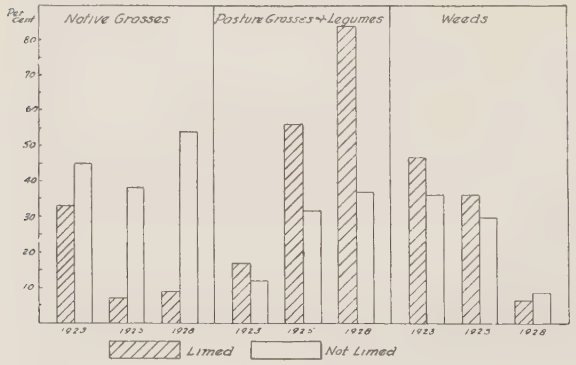


FIGURE 17. — Percentage of native grasses, pasture grasses and legumes, and weeds on the limed and unlimed halves of pasture plots on the Dairy farm in 1923, 1925, and 1928. Not grazed. Fertilizer treatment: manure and superphosphate

The application of superphosphate and lime also resulted in a striking improvement in the composition of the pasture grasses, as shown in Figure 19.

The application of nitrate of soda alone did not result in much

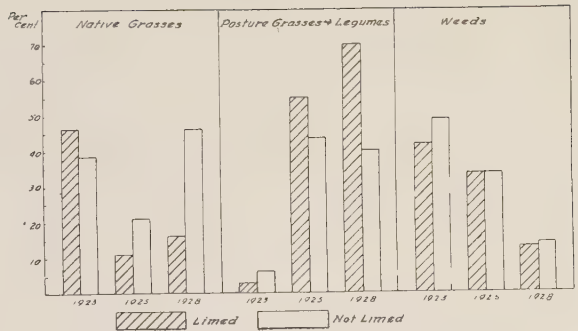


FIGURE 18.—Percentage of native grasses, pasture grasses and legumes, and weeds on the limed and unlimed halves of pasture plots on the Dairy Farm in 1923, 1925, and 1928. Not grazed. Fertilizer treatment: manure

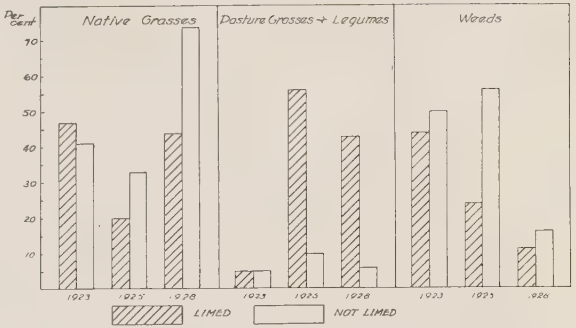


FIGURE 20.—Percentage of native grasses, pasture grasses and legumes, and weeds on the limed and unlimed halves of pasture plots on the Dairy farm in 1923, 1925, and 1928. Not grazed. Fertilizer treatment: nitrate of soda

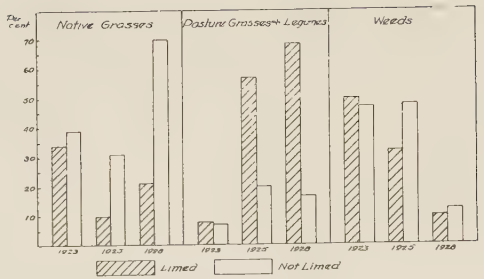


FIGURE 19.—Percentage of native grasses, pasture grasses and legumes, and weeds on the limed and unlimed halves of pasture plots on the Dairy farm in 1923, 1925, and 1928. Not grazed. Fertilizer treatment: superphosphate

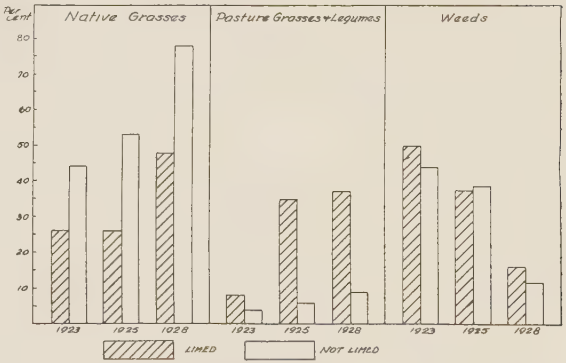


FIGURE 21.—Percentage of native grasses, pasture grasses and legumes, and weeds on the limed and unlimed halves of pasture plots on the Dairy farm in 1923, 1925, and 1928. Not grazed. Fertilizer treatment: none

change in the percentage of the various classes of plants either on the grazed or ungrazed parts. When nitrate was used with lime the percentage of pasture grasses and legumes was increased, but the increase was less than that obtained with superphosphate. Figure 20 shows the results.

TABLE 10.—*Average Yields per Acre on Seeded and Unseeded Pasture Plots on the Dairy Farm in 1924 to 1928*

Fertilizer Treatment	Lime Treatment	Average Yield 1924-28	
		Seeded	Not Seeded
Superphosphate	Limed	1804	1557
Superphosphate	Not limed	1045	1031
No fertilizer	Limed	1135	1217
No fertilizer	Not limed	800	911

The results obtained on the plots which received no fertilizer were similar to those where nitrate of soda only was applied. There was some increase in the percentage of pasture grasses and legumes on the limed half of these plots, but no great improvement resulted. The results are shown in Figure 21.

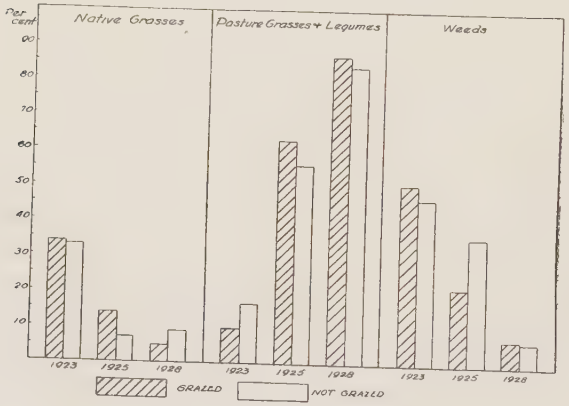


FIGURE 22. — Percentage of native grasses, pasture grasses and legumes, and weeds on the grazed and ungrazed halves of pasture plots on the Dairy farm in 1923, 1925, and 1928. Limed. Fertilizer treatment: manure and superphosphate

The average yields obtained from the various treatments on the Dairy farm and the percentages of native grasses and of pasture grasses are brought together in Table 9. The percentages of the different grasses are derived from the ungrazed half of each plot. Here, as was true on the Live Stock farm, the application of fertilizer and lime produced a striking increase in valuable pasture grasses. The application of superphosphate, manure, and lime increased the yield of valuable pasture grasses almost 3 times over the no-treatment plots, while the percentage of tame grasses, chiefly Kentucky bluegrass, increased from 9 to 84 percent. The improvement in the quality of the pasture obviously was greater in value than the yield alone would indicate.

Effect of Seeding.

The results obtained with the various seeding mixtures on the Dairy farm were very similar to those on the Live Stock farm. At the end of a period of years no advantage either in yield or composition of the pasture was obtained from using a complex seed mixture as compared to a more simple mixture. Where Mixture No. 2 was used a heavy growth of medium-red clover was obtained for one year on the limed and fertilized plots. This probably was due largely to the very favorable season for red clover.

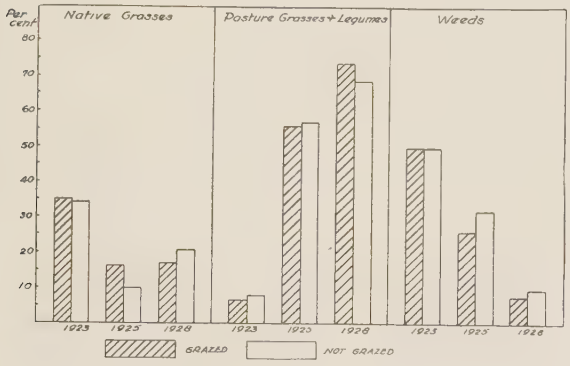


FIGURE 23. — Percentage of native grasses, pasture grasses and legumes, and weeds on the grazed and ungrazed halves of pasture plots on the Dairy farm in 1923, 1925, and 1928. Limed. Fertilizer treatment: superphosphate

In Table 10 several plots which received seed are compared with plots where no seed was applied. As may be seen from this table, increased yields were obtained from seeding on the lime-and-superphosphate plots. The average yields were 1,804 and 1,557 pounds per acre, respectively, on the seeded and unseeded halves. There was practically no difference in yield on the unlimed halves. No increase in yield resulted from seeding on either the limed or unlimed parts of the unfertilized plots. As will be seen in Table 14, seeding did not increase the percentage of pasture grasses and legumes. As was true on the other farm, the stand of bluegrass and white clover at the beginning of the experiment was sufficient eventually to replace the more undesirable native grasses and weeds when fertilizer and lime were applied.

TABLE 11.—*Average Yields per Acre on Cultivated and Uncultivated Pasture Plots on the Dairy Farm in* 1924 *to* 1928

Fertilizer Treatment	Lime Treatment	Average Yields 1924-28	
		Cultivated	Not Cultivated
No fertilizer	Limed	1273	997
No fertilizer	Not limed	866	733

Effect of Cultivation.

In Table 11 the yields on a series of plots which were cultivated by means of a disk harrow are compared with a similar uncultivated

series. As was true on the Live Stock farm, seeding and cultivation alone resulted in only a small increase in yield on both the limed and unlimed parts of the plots.

TABLE 12.—*Yields per Acre for the Years* 1924 *to* 1928 *and Average Yields on the Pasture Plots on the Dairy Farm, Where Phosphate Was Used with and without an Application of Lime*

Fertilizer Treatment	Lime Treatment	Yields in Pounds per Acre					Average 1924-28
		1924	1925	1926	1927	1928	
Superphosphate..	Limed	1871	1858	1189	1854	2250	1804
Superphosphate..	Not limed	1158	673	541	1287	1566	1045

Yearly Variation in Pasture Yields

In Table 12 are shown the average yearly yields of all plots receiving superphosphate only. Here as on the other farm good yields were obtained in the first years of the experiment, when the clover made up a large bulk of the crop on the limed parts of the plots. This was followed by a lower yield in 1926 and then by a gradual increase as the bluegrass was developing.

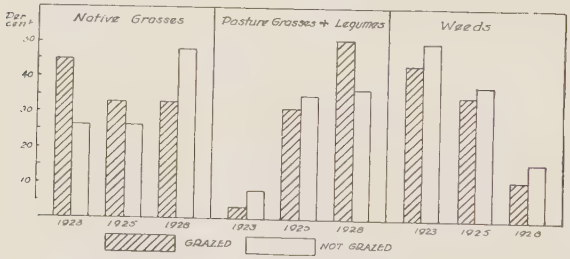


FIGURE 24. — Percentage of native grasses, pasture grasses and legumes, and weeds on the grazed and ungrazed halves of pasture plots on the Dairy farm in 1923, 1925, and 1928. Limed. Fertilizer treatment: none

Grazing vs. Mowing a Pasture

The results obtained on the grazed and ungrazed halves of the plots on the Dairy farm are shown in Table 14. The results of several treatments are also shown in Figures 22 to 24. As was true on the Live Stock farm, there was little difference in the various classes of plants on the grazed and ungrazed halves of the plots. Cutting the plots twice a year had about the same effect as moderate grazing.

DISCUSSION OF RESULTS

Certain of the treatments used indicate the possibilities of improving pastures. The soil involved in this investigation was a Dekalb clay loam. It was in a low state of fertility, too steep to make practicable the reestablishing of the pasture by plowing. The soil possessed, however, sufficient fertility to make improvement practicable. The soil on the Dairy farm was in a little better state of fertility than the soil on the Live Stock farm, as shown by the yields obtained. The effects of the various treatments and combinations of treatments

are very similar on the two farms, except that yields were higher on the Dairy farm.

On both farms the most striking improvement in the pasture resulted from an application of lime with a combination of manure and superphosphate. A seed mixture was applied with this treatment, and the plots were disked after the seeding. Manure alone or phosphate alone was not as effective as a combination of the two. On most farms in the state not enough manure is produced to warrant a general application on the pastures. The question, then, is whether one should apply either lime alone, superphosphate alone, or both. A complete commercial fertilizer was not included in these experiments; yet it is possible that on many farms a complete fertilizer together with lime may be the most profitable. An earlier experiment at this Station[6] indicated that an application of superphosphate and lime would give as good results as an application of complete fertilizer and lime. Before making a general application of fertilizer or lime on a pasture it is recommended that a preliminary trial be made on a small area as outlined in Circular 47 of this Station.

The application of lime, superphosphate, and Seed mixture No. 1 over a 6-year period cost approximately $18 per acre, exclusive of labor (an annual cost of $3 per acre). Where manure was applied in addition, the cost per acre was considerably more, and the exact amount would vary under different conditions. Considering the increased yields and the improvement in the quality of the pasture as shown in these experiments, it may be stated conservatively that where lime, superphosphate, and seed were applied, the carrying capacity was at least 3 times as great as before treatment. Where manure was applied in addition the improvement was still more striking. From the results obtained in these experiments it would seem that money invested in lime, superphosphate, and seed for pastures of this type will bring a very good return on the investment. For each dollar invested, the lime probably yielded the greatest return, and the seed the least. On both farms there seem to have been enough good pasture grasses so that where lime and fertilizer were applied, these grasses developed and a good sod was formed even where no seed was applied. If any of the treatments are to be left out, the cultivation and seed application are the first that should be omitted.

The application of nitrate of soda alone, when applied once every 3 years, although effecting some improvement of pasture when used in combination with lime, does not produce the results obtained by using superphosphate in combination with lime. On some pastures a combination of superphosphate with nitrate of soda, or a complete fertilizer when used with lime, probably will prove the most profitable treatment.

The experiments show conclusively that scattering seed over a

[6]W. Va. Agr. Exp. Sta. Bul. 177.

pasture of this type without other treatment is useless. In the pasture survey made in this state a few years ago[7], 98 percent of the farmers interviewed suggested reseeding the pasture as a means of improving it. Only a few more than one-half of these men suggested liming in addition, and less than one in 10 suggested applying fertilizers. A pasture must be considered as a piece of land producing a crop, just as much as any piece of land under cultivation.

Like seeding, disking a pasture without other treatment cannot be expected to produce any benefits. Good results may be obtained if lime and superphosphate are applied, and if cultivation is omitted entirely, particularly where topography of pasture makes cultivation difficult. If some bluegrass and white clover are present, seeding may also be omitted. The main consideration is to reduce the soil acidity by liming and then to supply fertilizer for the plants to utilize in their growth. Where a seed mixture is used, a simple mixture will probably be as effective as a more complicated one.

Although no experiments on the amount of grazing were included in these tests, attention should be called to the fact that best results cannot be expected from a pasture if it is kept too closely grazed, especially in the early part of the season. Cattle should be kept off the pasture until the grass has had opportunity to get a good start in the spring. After the grass has become well established there is less danger from damage to pasture by overgrazing.

[7]W. Va. Agr. Exp. Sta. Bul. 177.

Bulletin 236 August, 1930

Physiological Investigations on the Resistance of Peach Buds to Freezing Temperatures

by H. L. CRANE

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

AGRICULTURAL EXPERIMENT STATION STAFF

JOHN R. TURNER, Ph. D., LL. D., President of the University
F. D. FROMME, Ph. D. .....Dean and Director
GERALD JENNY, M. S., Agricultural Editor....JOHN C. JOHNSTON, Chief Clerk

AGRONOMY AND GENETICS
R. J. Garber, Ph. D.
Agronomist and Geneticist
E. P. Deatrick, Ph. D.
Associate Agronomist
W. H. Pierre, Ph. D.
Associate Agronomist
T. C. McIlvaine, Ph. D.†
Assistant Agronomist
G. G. Pohlman, Ph. D.
Assistant Agronomist
M. M. Hoover, M. S.
Assistant Agronomist
H. K. Rowley, M. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY
E. A. Livesay, D. Sc.
Animal Husbandman
Chas. V. Wilson, M. S.
Assistant Animal Husbandman
J. H. Longwell, M. A.
Assistant Animal Husbandman
J. H. Rietz, D. V. M.
Associate Veterinarian
R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman
R. S. Glasscock, M. S.**
Assistant in Veternary Science

CHEMISTRY
R. B. Dustman, Ph. D.
Agricultural Chemist
Chas. E. Weakley, Jr., M. A.
Assistant Chemist
L. P. Hansen, Ph. D.
Assistant Chemist
T. B. Leith, M. S.**
Assistant Chemist
I. J. Duncan, B. S.
Assistant in Agricultural Chemistry

DAIRY HUSBANDRY
H. O. Henderson, Ph. D.
Dairy Husbandman
L. M. Thurston, Ph. D.
Assistant Dairy Husbandman
K. S. Morrow, M. S.
Assistant Dairy Husbandman
L. F. Sutton, B. S. Agr.‡
Assistant Dairy Husbandman
R. A. Ackerman, M. S. Agr.
Assistant in Dairy Husbandry

ENTOMOLOGY
L. M. Peairs, Ph. D.
Entomologist
W. E. Rumsey, B. S.**
State Entomologist
Edwin Gould, B. S. Agr.
Assistant in Entomology

FARM ECONOMICS
A. J. Dadisman, Ph. D.
Farm Economist
F. D. Cornell, Jr., M. S.
Assistant Farm Mechanician
W. W. Armentrout, M. S.
Assistant Farm Economist
R. O. Stelzer, B. S.
Assistant in Farm Economics

HOME ECONOMICS
Rachel H. Colwell, M. A.
Home Economist
Hazel C. Cameron, M. A.
Research Specialist in Nutrition

HORTICULTURE
H. E. Knowlton, Ph. D.
Horticulturist
K. C. Westover, M. S. Agr.
Assistant Horticulturist
F. W. Craig, M. S. Agr.**
Assistant Horticulturist
Leif Verner, M. S.
Assistant Horticulturist
M. B. Hoffman, M. S.
Assistant in Horticulture
E. N. McCubbin, M. A.
Assistant in Horticulture
A. P. Dye, M. S. Agr.
Assistant in Horticulture

PLANT PATHOLOGY
C. R. Orton, Ph. D.
Plant Pathologist
Anthony Berg, M. S.
Associate Plant Pathologist
L. H. Leonian, Ph. D.
Associate Plant Pathologist
F. J. Schneiderhan, M. S.
Associate Plant Pathologist
E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY
Horace Atwood, M. S. Agr.
Poultry Husbandman
T. B. Clark, B. S. Agr.
Assistant in Poultry Husbandry

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Sub-Station, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

TABLE OF CONTENTS

	Page
Acknowledgements	5
Introduction	5
Theories in regard to freezing injury and resistance of plant tissue to low temperatures	6
Factors involved in resistance to freezing injury	6
Environmental factors that influence freezing injury	7
Characteristics of winters in West Virginia	10
Description and comparison of the varieties used	12
Materials and general methods	12
Materials	12
Methods used in determining the percentage of fruit-bud formation and winter killing	13
Methods used in collecting samples for chemical analyses	13
Methods used in determining dry weight and total nitrogen	14
Methods used in the determination of carbohydrates	14
Histological methods	14
Mathematical significance of the data	15
PART I.—The Influence of Pruning and Nitrogen Applications on the Formation, Composition, and Hardiness of Peach Fruit Buds	15
Treatments	16
Experimental results	18
Growth response	18
Formation and hardiness of fruit buds	18
Formation of fruit buds	18
Hardiness of the buds	20
Relation of length of shoot to the formation and hardiness of fruit buds	22
Fruit-bud formation	22
Hardiness of the buds	24
Dry weight of the fruit buds	25
Bound water of the fruit buds	26
Size and increase in dry weight of the fruit buds	28
Percentage of total nitrogen in the fruit buds	30
Total nitrogen in one thousand fruit buds	33
Composition of the fruit buds	33
Discussion	34
PART II.—The Influence of Ringing and Nitrogen Applications on the Formation, Composition, Growth, and Hardiness of Fruit Buds	37
Treatments	37
Experimental results	38
Growth response	38

Page
Formation and hardiness of the fruit buds ---- 39
Formation of fruit buds ---- 39
Hardiness of the buds ---- 42
Relation of length of shoot to the formation and hardiness of fruit buds 44
Dry weight of the fruit buds ---- 45
Bound water of the fruit buds ---- 46
Size and increase in dry weight of the fruit buds ---- 46
Percentage of total nitrogen in the fruit buds ---- 48
Total nitrogen in one thousand fruit buds ---- 49
Composition of the fruit buds ---- 51
Growth and development of the buds during the winter months ---- 52
Increase in diameter of the naked fruit buds ---- 52
Development of the pollen ---- 54
Discussion ---- 56

PART III.—The Influence of Partial Defoliation and Nitrogen Applications on the Formation, Growth, and Hardiness of Peach Buds ---- 57
Treatments ---- 57
Experimental results ---- 58
Growth and blooming response of the trees following partial defoliation 58
Formation and hardiness of the fruit buds ---- 60
Fruit-bud formation ---- 60
Hardiness of the buds ---- 60
Dry weight of the fruit buds ---- 62
Percentage of total nitrogen in the fruit buds ---- 62
Total nitrogen in one thousand fruit buds ---- 64
Growth and development of the fruit buds ---- 64
Increase in diameter of the naked fruit buds ---- 64
Development of pollen ---- 66
Discussion ---- 69
General Discussion ---- 71
Summary ---- 73
Bibliography ---- 76

ACKNOWLEDGMENT

The writer wishes to acknowledge his indebtedness and to express appreciation and thanks to all who have assisted in any way in the conduct of this study; especially to Dr. Lewis Knudson, professor of plant physiology at Cornell University, under whose direction the problem has been carried out, for his most helpful and appreciated criticisms and suggestions; to the members of the Department of Agricultural Chemistry of West Virginia University for their cooperation and assistance, particularly to Dr. Lorenz Hansen, for making the carbohydrate analyses; to Messrs. C. E. Weakley and L. C. Shriver for making the total-nitrogen determinations. Thanks are also extended to Messrs. Allan Tenor and M. B. Hoffman, of the Department of Horticulture of the same institution, for their help in collecting samples and data.

Physiological Investigations on the Resistance of Peach Buds to Freezing Temperatures

by H. L. CRANE†

WHILE a considerable number of investigations have been made on the causes of injury by freezing temperatures, within more recent years attention has been devoted to the causes of resistance. The subject is not only of theoretical interest but of practical importance because of the great losses that result annually by freezing injury to the fruit buds of peach, plum, apple, cherry, and other fruit trees. The peach is particularly subject to damage by freezing and it is not uncommon to lose a season's crop because of death of the fruit buds by low temperatures. In addition to the killing of the fruit buds during those months when the plant is considered dormant, the essential floral organs may be killed by freezing temperatures when the trees are in flower. The latter may be controlled in part by heating methods. Generally speaking, loss from this late injury is less than from the killing of buds during the dormant season.

The killing of fruit buds during the dormant period varies with the variety. Experience as well as theoretical considerations also lead to the conviction that the resistance of the fruit buds to low temperature is determined in part by the character of growth of the tree during the season preceding the winter injury. It seems reasonable therefore to conclude that environmental conditions and cultural practices may influence the resistance to low temperature. While it is not possible to control the climatic factors, it is possible to control cultural practices. To a certain extent, therefore, resistance to low temperature may be increased when a fuller knowledge of the subject is available. With this purpose in mind the present investigation was undertaken.

This paper is the result of experiments conducted through a period of three years on the influence of cultural practices and other treatments on the hardiness of peach fruit buds of two varieties — Salwey and Greensboro. In addition to the observations on resistance, chemical and histological studies were made in order to develop more precise knowledge concerning the growth and physiological changes related to resistance and susceptibility to low temperatures. In the main, three distinct treatments were followed. The first considers

†Resigned November, 1929.

the influence of different kinds of pruning with and without nitrogen applications, the second considers the influence of ringing with and without nitrogen, and the third, partial defoliation with and without nitrogen. In addition, special consideration is given to the temperature relations prevailing in West Virginia during the winter months and to the bearing of these temperature conditions on freezing injury. A comparison is also made of the gross characters of the Salwey and Greensboro varieties, since the Greensboro is hardy, while the Salwey is readily injured by low temperature. Before considering the experimental work it will be desirable to consider briefly the views that have been proposed in respect to the characteristics of plants associated with resistance to freezing injury.

THEORIES IN REGARD TO FREEZING INJURY AND RESISTANCE OF PLANT TISSUE TO LOW TEMPERATURES*

Factors Involved in Resistance to Freezing Injury

Water content has been shown to affect the hardiness of plants. Working with peach buds Johnson *(53)* showed that the moisture-dry weight ratio was an index of hardiness, as an increase in the ratio resulted in tender buds. Shutt *(82)* reported that twigs of hardy varieties of apples were low in moisture. The results of Beach and Allen *(7)*, Strausbaugh *(84)*, and Hildreth *(46)* agree with those of Shutt *(82)*, although they found that shoots of hardy varieties after prolonged exposure to cold contain a higher percentage of water than the less hardy ones. This was due to the fact that tender varieties give up water more readily than hardy ones. Lott *(59)* found a marked correlation between the bound water and hardiness in brambles. Low moisture content is also a factor in the hardiness of wheat as reported by Sinz *(83)*, Akerman and Johansson *(2)*, Newton *(69)*, and Martin *(61)*, while Rosa *(77)* has indicated that this is true for certain vegetable plants.

The imbibitional force of the cells was suggested by Mueller-Thurgau *(66)* as an important means of preventing the loss of water from the cells by freezing. Strausbaugh *(84)*, Newton *(67)*, Dorsey and Strausbaugh *(28)*, Dunn and Bakke *(32)*, Lott *(59)*, and Martin *(61)* hold similar views. Hooker *(48)* and Rosa *(77)* concur in this view and attribute the greater hardiness of hardened plants to a larger content of pentosans than is present in the non-hardened ones. Newton *(69)*, Hildreth *(46)*, Lott *(59)*, Doyle and Clinch *(29, 30)*, and Delong *(27)*, however, found no consistent relation between pentosan content and hardiness.

*The literature dealing with the subjects of freezing injury and resistance of plant tissue to low temperature has been carefully reviewed by Chandler (16) Hildreth (46) Martin (61) and others. For this reason only a brief sketch of the ideas advanced which have a particular bearing on the problem at hand will be considered here. A rather complete bibliography, however, is included with this report.

Maximow *(62)* and Chandler *(16)* studied the relation of sap concentration to hardiness and found that the plant tissue showed a greater resistance to freezing than could be accounted for by the increased sap concentration. Ohlweiler *(70)* used a number of plant species and reported a relation between sap concentration and hardiness. These results were substantiated by Rosa *(77)*, Harvey *(43)*, Carrick *(14)*, Harris and Poponoe *(42)*, Haas and Halma *(41)*, and others. Winkler *(93)* showed that the cell sap of plants placed in cold chambers increased in osmotic concentration rather quickly. On the other hand, the work of Apelt *(4)*, Rein *(75)*, and Salmon and Fleming *(79)* showed no definite correlation between hardiness and osmotic concentration of the cell sap. Newton *(68)* properly points out that the osmotic concentration of the vacuolar sap contributes to the water-retaining power of the cells, but as an explanation of hardiness it is quite inadequate.

Molisch *(63)*, was of the opinion that small cells contribute to hardiness. This view was supported by the work of D'Arsonval *(25)*, Wiegand *(92)*, and Rosa *(77)*. Beach and Allen *(7)* found no difference in the structure of apple stems of hardy and tender varieties, yet they thought hardiness was related to the hardness of the wood. On the other hand, the investigations of Rein *(75)*, involving a large number of plant species, showed no relation between size of cells and hardiness. It should be pointed out that small, thick-walled cells are usually the result of slow growth, early maturity, and low nitrogen and high carbohydrate content which may be caused by a deficiency of water or nitrogen or by the lack of some essential element.

Schaffnit *(80)* concluded that as tissues are hardened, the proteins of the cells are split into simpler forms, less readily precipitated than those of non-hardened tissue. Harvey *(43)* found that on hardening herbaceous plants the amino nitrogen increases greatly, and that the simpler forms of proteins are not so easily precipitated by freezing or by the addition of acids as the more complex forms. Newton *(69)*, working with wheat, and Hildreth *(46)*, with apples, found that the ratio of amino to total nitrogen increases in the fall but that no consistent relationship exists between amino nitrogen and hardiness.

Environmental Factors That Influence Freezing Injury

Maturity has been shown to be of paramount importance in determining the degree of cold resistance of plants. Emerson *(34)* believed that resistance to cold in fruit trees often was due almost wholly to the habit of early maturity rather than to constitutional hardiness, and Macoun *(60)* came to the conclusion that trees or shrubs to survive severe winters must ripen their wood early. Emery *(35)* pointed out that temperatures well above 0°F. in early winter often cause more injury than -30° or -40° later. Green and Ballou *(39)* report that peach trees growing in rich, moist soil or under late cul-

tivation were more severely injured because of immaturity than similar trees growing in sod or under grass mulch. Emerson *(33)* found a similar relationship . Thayer *(87)* found that young peach trees, because of their late growth, bear more tender fruit buds than the older trees that have a shorter duration of growth. Gladwin *(36)* reports that severe pruning of grapes decreased the hardiness of the wood and buds by delaying maturity. Bradford and Cardinell *(12)* say that lack of maturity is the greatest factor in inducing winter injury, and that late cultivation or heavy fertilization have proved to be unwise practices.

Because of differences in the degree of maturity in early winter, plants normally hardy may in certain instances be more susceptible to freezing injury than less hardy ones. Such conditions have been reported by Blake and Farley *(9)*, Greene *(40)*, Bradford *(11)*, Chandler *(17)*, and others.

It has been reported by several investigators that by mid-winter the condition or state of hardiness may be lost, at least to some degree. The studies of Askenasy *(5)* with sweet cherry and those of Knowlton and Dorsey *(56)* with peaches showed that the fruit buds make a continuous growth and development from fall until spring. Whitten *(90)*, Howard *(50)*, Chandler *(15)*, and Hooker *(49)* have pointed out that the growth of the buds during the warm weather of the winter made them particularly susceptible to injury by freezing temperatures. Blake and Connors *(10)* report that Elberta and other similar varieties start into growth the first warm days in the winter and later are severely injured, while such varieties as Carman and Greensboro respond less quickly and escape with slight damage. Davis *(26)* has shown that sour cherry buds having withstood temperatures of -30°F. during January without injury were killed by much higher temperatures in late February and early March. The critical temperature depends on the degree of maturity in early winter and on the stage of development of the buds in late winter, as has been pointed out by Howard *(50)* and by West and Edlefsen *(89)*.

Another important factor in determining the injury resulting from a certain temperature is the rate of temperature fall. Chandler *(16)* reports that when peach buds were cooled rapidly to -17°C., from 97 to 100 percent were killed, but when they were cooled slowly to -19.5°C., only 15 to 18 percent were killed. Similar results for apple roots and shoots have been shown by Carrick *(13)*, Potter *(73)*, and Hildreth *(46)*. The greater injury resulting from a rapid fall in temperature is of particular significance for sections like West Virginia, which are subject to rather sudden and wide deviations in the daily minimum temperatures during the winter.

The length of the rest period has been emphasized by Strausbaugh *(84)* as important in determining the relative hardiness of plum varieties. Chandler *(15)* suggested that by prolonging the period of growth of peach trees by late cultivation, by pruning, or by fertili-

TABLE 1.—*Characteristics of the Winter Months, December, January, and February, at Morgantown for the Winters of* 1925-26, 1926-27, *and* 1927-28

Winter	Month	Rainfall in inches	Min. Temp. for Month	Max. Temp. for Month	Mean Min. Temp.	Mean Max. Temp.	No. of Days Max. Temp. 55°F. or Above	No. of Periods Max. Temp. 55°F. or Above	No. of Days Min. Temp. Below 32°F.	No. of Days Max. Temp. Below 32°F.
1925-26	December	1.52	0	62	24.7	40.4	6	3	20	8
	January	2.88	—8	59	23.6	40.1	4	3	23	8
	February	4.59	14	58	25.7	41.4	3	2	21	2
1926-27	December	3.81	0	61	25.2	40.9	2	1	20	6
	January	4.28	5	63	24.3	39.6	4	3	24	7
	February	4.35	19	67	31.6	49.2	11	3	15	2
1927-28	December	3.16	5	70	25.5	42.2	8	4	22	11
	January	1.30	—2	67	22.2	41.5	6	2	19	8
	February	2.87	7	61	25.6	42.6	3	3	21	4

zation, the entrance of the trees into the rest condition would be delayed and consequently they would come out of it later in the winter. As a result, when the rest was initiated later, the buds would make less growth in the warm days of winter and would be more resistant to the low temperatures occurring in the spring. The evidence presented by Howard *(51)*, Johnson *(54)*, Hodson *(47)*, and Knowlton and Dorsey *(56)* show that the rest period in peaches is over by early January, and thus it could not have a restraining influence on the growth of the buds during late winter.

A consideration of the evidence on freezing injury reveals that the state or composition of the protoplasm is the critical factor in resistance. The observations of others previously discussed reveal likewise that what is commonly termed maturity predetermines the relative resistance of the plant to freezing temperatures. Maturity of woody plants means that cellular activity in relation to growth is at a minimum point, water content is low, the reserve foods are of high molecular weight, and cell wall thickening has been entirely completed. Since these are the characteristics of the resting condition, the inference seems permissible that the plant in that condition is less susceptible to freezing temperatures.

Characteristics of Winters in West Virginia

It is apparent that other factors as well as temperature are involved. For a clearer understanding of the problem and to define certain conditions of the experiment, consideration must be given to the temperatures prevailing at Morgantown, West Virginia.

The winters in the latitude of West Virginia are mild and open. Usually there are one or more periods when the temperature may remain well above the freezing point for several days. These warm periods are followed in many instances by a rapid drop in temperature—close to 0°F. These conditions generally cause the winter killing of the fruit buds. Knowlton and Dorsey *(56)* report that late in January, 1925, nearly all buds of the tender and semi-hardy peach varieties in the orchard of the Experiment Station at Morgantown were killed after a warm period followed by a sudden drop in temperature to -9°. During the fall the weather is generally warm, sunny, and favorable for late growth of the trees. In an occasional winter like that of 1918-19, serious damage may result to the trees and fruit buds if the temperature approaches 0° before maturity has developed. Such occurrences are, however, infrequent.

The winter of 1925-26 caused severe winter killing of peach buds, especially those of tender varieties. In Table 1 are given the maximum and minimum temperatures from December to February inclusive. These data show that a maximum temperature of 55°F. or higher occurred 8 times during the months of December, January, and February. The minimum temperature for the winter was -8° on Jan-

uary 29. This temperature was sufficiently low to kill all of the Salwey buds and from one-half to three-fourths of the Greensboro buds on trees in the experiments to be reported later. On January 16 the maximum temperature reached 57°. The weather remained warm for a week, with the minimum temperature well above freezing for five days. This was followed by a colder period, then by a slight rise in temperature, and finally the drop to -8°.

The winter of 1926-27 was mild and the minimum temperature was 0°F. on December 18. Temperatures of 5° were recorded on January 16 and 27. Immediately preceding the fall in temperature on January 27, the maximum temperature was as high as 63°, with the minimum temperature well above freezing for several days. No fruit buds were killed by the 0° temperature of December 18, but the temperature of 5° on January 27 caused the death of about 25 percent of the Salwey buds.

Following an exceptionally late, warm, and wet October and November, the winter months of December, January, and February of 1927-28 were drier than normally. The minimum temperature for December was 5°F. It occurred on the night of December 9, immediately after a warm period, during which the maximum temperature was 62° on the seventh. This temperature killed a small percentage of the buds of the Salwey. The minimum temperature of -2° for the winter occurred on January 2, immediately following a warm period of three days wherein the maximum temperature ranged from 54° to 57° and the minimum temperature from 33° to 52°. The minimum temperature of -2° caused considerable injury to the fruit buds of both Greensboro and Salwey varieties.

February was considerably warmer and drier than usual, and was followed by a March colder than the average. It was, however, unusually warm for three days from March 11 to 13, when the maximum temperature varied from 60° to 80°F. and the minimum temperature from 32° to 50°. This was followed by a minimum temperature of 23° on March 17, which killed a rather large percentage of the pistils of certain fruit buds of the Salwey and a few of the Greensboro.

The fact that the greatest damage results when wide fluctuations in temperature occur, as, for example, a change from 55° or 60° to 0° or 10°F. within a few days, is of great significance. This implies that during the winter and early spring, protoplasmic changes are induced, at least in part, by the high temperatures, making the plant tissue particularly susceptible to injury and death by temperatures below the freezing point. A knowledge of these changes would of course contribute to a clearer understanding of the causes of death by freezing temperatures. The relation of these temperature fluctuations to freezing injury will be considered subsequently in the various experiments and discussion.

DESCRIPTION AND COMPARISON OF THE VARIETIES

Hardiness is determined to a considerable degree by the protoplasmic activity or growth response of the tissues during the warm periods in mid-winter. For these reasons it seemed desirable to make a careful study of the growth behavior and certain chemical characteristics of two markedly different varieties of peach, both growing under the same conditions. One of these varieties, the Salwey, usually is quite susceptible to injury by freezing temperatures; the other, Greensboro, is strikingly resistant. Since low temperatures affect these varieties quite differently, it was thought that a comparison of the two would reveal data not only of theoretical importance but of practical value in formulating possible corrective cultural methods.

A comparison of Greensboro and Salwey as regards growth and fruiting characteristics is significant. Both varieties are vigorous in growth, and they produce large trees. The Greensboro has an open, spreading top, while that of the Salwey is upright, spreading and becoming drooping and dense. The Greensboro normally produces many short, thick, spur-like shoots, while the Salwey bears a much smaller number of such growths, and these usually are longer and more slender. The Greensboro makes its growth early in the season. Usually growth elongation stops, and fruit-bud initiation begins about a month before that of the Salwey. Under West Virginia conditions the fruit of the Greensboro matures from the middle to the last of July, while the Salwey does not ripen until the middle to the last of September. The fruit buds of the Greensboro are large as compared to those of the Salwey. This greater size of the Greensboro buds is due to a larger number of bud scales, heavier pubescence, and a larger bud cavity than in the case of the Salwey. Both varieties bloom at approximately the same time.

MATERIALS AND GENERAL METHODS

Materials

The orchard used in these investigations, located at Morgantown, was planted in the spring of 1916, consisting of 8 rows of 15 trees planted diagonally, 16 by 26 feet apart. Cultivation usually was started about the time of bloom and was of sufficient frequency to prevent weed growth. In June soybeans were sown and an application of 300 to 400 pounds of 16-percent superphosphate was made. When the soybeans had attained their maximum development they were disked down, and a cover crop of rye was seeded. No nitrogen-carrying fertilizers were applied until the spring of 1924, when a four-pound application of nitrate of soda was made at the time of flowering to alternate trees in each row; these same trees received the same amounts of nitrate of soda in the years following.

Three trees of each variety, selected as far as possible for uniformity of size, vigor, and growth response, were used in each treatment.

During the course of these studies the only fruit produced was in the summer of 1926, when the Greensboro bore a light crop.

Methods Used in Determining the Percentage of Fruit-Bud Formation and Winter Killing

The number of fruit buds formed and the total amount of winter killing was determined when the buds were in the pink stage.

Each winter after a particularly cold night or a hard freeze following a warm period the orchard was visited. Observations were made on the injury to the buds, — none, however, until the weather had become sufficiently warm after the cold period for the buds to have thawed completely and turned brown. Buds at this time were sectioned and examined macroscopically for injury.

In determining the percentage of fruit-bud formation and of hardiness, only unblanched shoots were used. The length of the shoot was measured, and the number of nodes and buds for the shoot counted; likewise the number of buds which from outside appearances were alive and would open normally into full bloom. In the spring of 1928 certain treatments showed a considerable number of buds with their pistils killed. In this case a separate count was made of those injured. In calculating the percentage of fruit buds formed it was considered that, as a maximum, two fruit buds should be formed at each node. Hence the number of buds was divided by two times the number of nodes and the result was multiplied by 100. The percentage of live buds was calculated from the number formed and the number alive. To obtain these data 30 to 70 shoots from each tree were used. These shoots were taken promiscuously from all parts of the trees in an attempt to get a random sample.

Methods Used in Collecting Samples for Chemical Analyses

All samples of buds for dry weight, nitrogen, and carbohydrate analyses were collected in the morning, usually from 9 to 10 o'clock, on clear days. Representative one-year, unbranched shoots of about 10 to 15 inches in length from all parts of the tree were cut, tied in a bundle, labeled, placed in a collecting can, and taken to the laboratory as soon as all samples were collected. An attempt was made to collect the samples in the field in weighing bottles. This had to be discontinued because of the slowness of the operation. A comparison of the two methods of taking samples was made, and the laboratory method gave the more uniform results. The buds were removed from the shoots with approximately the same amount of scales, bark, and wood. The buds in each sample were counted when removed and were placed in open Petri dishes, in which they were dried. All of the fruit buds from each shoot were included in the sample. For the dry weight and nitrogen determinations, samples were taken from each of the three trees in each treatment, and the analyses made separately.

Methods Used in Determining Dry Weight and Total Nitrogen

The fruit buds were dried just as they were removed from the shoots. For the dry weight determinations a sample of two to three gm. or about 200 buds were used. These were first dried in a constant temperature oven at 30° C. for 144 hours. It was found by trial that at this temperature and for this time the samples reached constant weight. To determine the amount of bound water or that held tenaciously by the buds, the samples were again dried for 72 hours in vacuo at 70°C. with a vacuum of 26 to 27 inches of mercury. The entire samples were then used for the total nitrogen determinations which were made by the official Kjeldahl-Gunning-Arnold method.

Methods Used in the Determination of Carbohydrates

Because of the nature of the material the samples were small, and from 6 to 14 gm. green weight were used for the carbohydrate analyses. Each sample of buds was placed in a jar thoroughly mixed by shaking, and about two gm. of the material was removed for dry weight and total nitrogen determinations. The remaining 4 to 12 gm. of buds were weighed, giving total green weight. The samples were prepared as quickly as possible, covered with 95 percent alcohol, a small quantity of calcium carbonate added, and heated at 70°C. for one hour. The methods of analysis were as follows: the alcohol was evaporated off the samples in vacuo at 75°C. The dry material was then extracted with ether in a Soxhlet extraction apparatus for approximately 12 hours, giving the ether soluble material. The residue was then extracted with 80 percent alcohol in a manner similar to the ether extraction. The alcohol solution was made up to volume and an aliquot portion taken for (a) determination of reducing sugars and (b) total sugars. The residue from the alcohol extraction was dried in an oven in vacuo at 75°C. for approximately 12 hours. Samples were taken for starch determinations and the residue from this was analyzed for acid hydrolyzable materials. Methods used for the analysis of reducing sugars, total sugars, starch, and acid hydrolyzable (hemi-cellulose) were those of the Association of Official Agricultural Chemists.

Histological Methods

During the winter of 1927-28 the development of the buds was followed by histological methods. Two collections of buds were made, the first on November 29, the second on February 6. Samples were killed and fixed from eight different treatments of each of the two varieties. In collecting the material, uniform shoots of 12 to 15 inches long were cut from various locations on two of the three trees in each treatment. The buds from these shoots were separated into two samples: basal and terminal buds. In taking the sample of the basal buds those borne on the first three or four nodes were dis-

carded because of the small leaves usually borne at these nodes. The buds used in the basal sample were taken from the fourth to seventh nodes from the base of the shoot. The buds comprising the terminal samples were taken from the last five or six nodes on each shoot, none being discarded. Schaffner's chrom-acetic fixative and the paraffin method of embedding were used. The material was sectioned from five to ten microns thick and stained with Fleming's triple stain. In all over 800 slides were made for these studies. Two measures of growth were used in following the growth of the buds during the winter months: the diameter increase of the buds measured through the ovule case, and the development of the pollen. In all instances the most advanced degree of pollen development found in the various anthers of each bud was used as the stage of development for that bud.

Mathematical Significance of the Data

In some cases in which the mean of a series of results is given the probable error has been calculated, using Bessel's formula.

It is realized that in most groups the population was small and not distributed normally. The error as calculated, therefore, is not a true error, but it is included in the cases where it seemed warranted in order to call attention to the probable significance of the data and to prevent the drawing of conclusions not justified. Where comparisons are made the odds as to the significance of a difference have been calculated by the use of Pearson's *(71)* tables, from the ratio of the observed differences to the error of the difference as calculated by the usual formula. In some cases the correlation coefficient has been calculated to show the relationship between characters by the usual formula as applied to the short method.

PART I

The Influence of Pruning and Nitrogen Applications on the Formation, Composition, and Hardiness of Peach Fruit Buds

Hardiness is related to maturity of the tissue. It is probable, therefore, that cultural practices which delay or hasten the maturation of tissues have an influence on their resistance to freezing temperatures. For this reason experiments were made to determine the influence on hardiness of two practical procedures: namely, pruning and the use of nitrate of soda. Numerous experiments have shown that these practices, within limits, stimulate the growth of the trees somewhat in proportion to the severity of the pruning or to the amount of nitrate of soda applied. The growth response following such treatments is determined to some extent by the vigor of the trees. For this reason every precaution was taken to use trees of uniform size and vigor.

Treatments

The object of the treatments employed was to alter the carbohydrate-nitrogen relationships and the growth of the trees so that their effects on the hardiness of the fruit buds could be determined. In the spring of 1925 the trees of every other row in the orchard already described were headed back so that the main scaffold limbs were four feet long, and those of the alternate rows were cut back to two feet. Certain rows received one, two, and three summer prunings. The first summer pruning was made June 18, when the new shoots were about one foot long. It consisted of removing the excess shoots. The second summer pruning was given July 20. As before, the excess shoots were removed, and those which had grown beyond the general contour of the tree were headed back. The third summer pruning was given August 14, of the same nature as the second. The effects of these treatments on the growth of the trees has been reported *(21)*.

The following spring (1926) all of the trees, excepting those of Row 31, which were used as checks, and the Salwey trees of Row 27, were very lightly pruned in late winter (corrective pruning). Very little wood was removed, as only interfering shoots or those which had grown beyond the general contour of the tree were removed or cut back. The Salwey trees of Row 27 again were pruned twice during the early summer, at approximately the same time and in the same manner as the first two summer prunings of the previous year. A four-pound application of nitrate of soda was made each spring at the time of blooming to alternate trees in each row as already mentioned. Briefly, the above and subsequent treatments were as follows:

Row 25. Greensboro: 1925, Light dormant and one summer pruning not used after the spring of 1926.

Row 27. Greensboro: 1925, Light dormant and two summer prunings. 1926 and 1927, Corrective pruning.

Salwey: 1925, Light dormant and two summer prunings. 1926, Corrective and two summer prunings. 1927, Corrective pruning.

Row 29. Greensboro: 1925, Light dormant and three summer prunings; 1926, Corrective pruning and every other tree received 16 pounds of nitrate of soda applied in four equal applications on April 30, June 9, June 24, and July 15. These trees were not used after the spring of 1927.

Row 31. Greensboro: 1925, Light dormant pruning; 1926 and 1927, no treatment. These trees were used as the checks.

Salwey: Same as the Greensboro.

Row 32. Greensboro: 1925, Heavy dormant pruning. These trees were not used after the spring of 1926.

TABLE 2.—*Formation and Hardiness of Greensboro Fruit Buds*, 1925-26

Row No.	Treatment	Total No. of Shoots Used	Total Length of Shoots	Total No. of Nodes	Total No. Buds Formed	Total No. Buds Alive After Last Freeze	Percentage of Buds Formed	Percentage of Buds Alive	Average Percentage of Buds Alive
32	Heavy dormant pruning	105	1176	1335	1692	766	63.37	45.27	45.03±3.37
32	Heavy dormant pruning +nitrogen	105	1217	1365	1791	472	65.60	26.35	25.92±2.54
31	Check	105	1328	1542	2072	1105	67.18	53.33	53.52±3.23
31	Nitrogen	105	1431	1631	2279	1061	69.86	46.55	46.55±2.77
25	1 summer pruning	105	1291	1546	2088	823	67.53	39.41	39.69±2.70
25	1 summer pruning + nitrogen	105	1377	1601	2257	769	70.49	34.07	33.95±3.68
27	2 summer prunings	105	1285	1511	2011	637	66.54	31.67	31.67±0.48
27	2 summer prunings +nitrogen	105	1332	1479	1841	597	62.24	32.43	32.43±0.42
29	3 summer prunings	105	1526	1745	2440	937	69.91	38.40	38.88±2.54
29	3 summer prunings +nitrogen	105	1558	1772	2461	648	69.44	26.33	26.56±1.76
Total of all No-Nitrogen treatments		525	6606	7679	10,303	4268	67.08	41.42	
Total of all Nitrogen		525	6915	7848	10,629	3547	67.72	33.37	

		Difference*	Odds
Mean percentage of buds alive, no-nitrogen trees	42.44±1.63		
Mean percentage of buds alive, nitrogen trees	32.13±1.43	10.01±1.33	2,598.751.1

*For the reason that there is correlation between the various trees fertilized and those not fertilized, the probable error of the difference has been calculated according to the formula

$$\text{P. E.}_D = \pm .6745 \sqrt{\frac{S_a^2 + S_b^2 - 2rS_aS_b}{\frac{N}{N(N-1)}}}$$

Where **r** is the coefficient of correlation, **N** is the number of determinations, and **S** is the standard deviation.

EXPERIMENTAL RESULTS

Since pruning or the application of nitrogen influences the growth of the trees it was expected that not only the hardiness but the formation of fruit buds would be affected by these practices. For this reason the percentage of buds formed as well as those killed was determined by the methods already described. The peach produces the fruit buds on wood of the current season. For this reason emphasis has been placed on the relation of the length of the shoot on which the buds are borne to their formation and hardiness.

To determine whether the growth made by the trees in the season the fruit buds were formed had any influence on the composition and hardiness of the buds, determinations were made of the dry weight, bound water, total nitrogen, seasonal changes of these factors, and the carbohydrate content of the buds. The increase in dry weight of 100 buds and the gain in total nitrogen have been used as measures of the development of the buds during the winter months.

Growth Response

Following the pruning or nitrogen treatments of the spring of 1925, the growth of new shoots was greatly stimulated. In the case of the trees which received two or three summer prunings the growth response was not proportional to the severity of the pruning or to the amount of nitrogen available to the trees. The length of the shoots of the trees that were summer-pruned two or three times was little different from those summer-pruned once. However, the continued pruning reduced the leaf area so that carbohydrates were probably limiting. This is indicated by the long and slender roots produced which formed few secondary branches. The application of nitrate of soda greatly stimulated the growth of the trees, causing more and longer shoots to be formed and the leaves to be darker green in color and to be retained longer than those of similar trees not fertilized.

Formation and Hardiness of Fruit Buds

In Tables 2 and 3 are given the results on the formation and hardiness of the fruit buds for the seasons of 1925-26 and 1926-27, respectively. As regards the formation of fruit buds or, as it is commonly termed, the setting of fruit buds, the data are not wholly in agreement.

Formation of Fruit Buds

The formation of fruit buds on the Greensboro was not influenced by pruning or nitrogen applications to any appreciable extent during the season of 1925-26. (See Table 2.) This was rather surprising in view of the wide vegetative difference of the trees in the various treatments. The data for the season of 1926-27 (Table 3) show that the application of nitrogen seemed to increase fruit-bud formation on the Salwey but to decrease it on the Greensboro. When the Salwey trees were summer-pruned the formation of fruit buds

TABLE 3.—*Formation and Hardiness of Greensboro and Salwey Fruit Buds,* 1926-27

Variety	Row	Treatment	Total No. of Shoots	Total Length of Shoots	Total No. Nodes	Total No. of Buds Formed	Total No. of Buds Alive After Last Freeze	Average Percentage of Buds Formed	Average Percentage of Buds Alive	Difference in Percentage of Buds Alive	Odds
Salwey	31	Check	109	979	1497	2166	1945	69.66±0.23	89.63±1.04		
	31	4 pounds nitrate of soda	105	735	1233	1544	1448	62.33±1.82	93.88±0.71	4.25±1.26	43:1
	29	No nitrogen	106	993	1497	2192	1973	72.66±1.54	89.87±0.95		
	29	16 pounds nitrate of soda	102	952	1541	1944	1841	62.50±1.19	94.83±1.07	4.96±1.43	51:1
Greensboro	31	Check	111	1261	1945	1182	963	30.43±0.45	81.39±1.66	3.89±2.40	2:1
	31	4 pounds nitrate of soda	108	1393	1979	1420	1099	35.98±1.37	77.50±1.74		
	27	2 summer prunings	108	1121	1848	938	712	25.56±1.42	76.05±0.89	4.36±1.10	132:1
	27	2 summer prunings +4 pounds of nitrate of soda	108	1329	2180	1168	836	26.89±1.71	71.69±0.65		

TABLE 4.—*Relation of Length of Shoots and Effect of Nitrogen Applications on Formation and Hardiness of Greensboro Fruit Buds,* 1925-26

Length of Shoots	Treatment	Total No. of Shoots	Average Length of Shoots	Total No. of Nodes	Total No. of Buds Formed	Total No. of Buds Alive After Last Freeze	Average Percentage of Buds Formed	Average Percentage of Buds Alive	Percentage Difference in Buds in Favor of no Nitrogen	Odds
0″- 6″	No nitrogen	81	4.69	620	648	346	51.64±1.57	53.77±1.95	10.77±3.21	42:1
0″- 6″	Nitrogen	96	4.93	736	845	364	57.15±1.51	43.00±2.55		
7″-12″	No nitrogen	225	9.46	2635	3270	1488	61.73±0.90	44.77±3.23	11.51±3.94	19:1
7″-12″	Nitrogen	201	9.38	2305	2903	985	62.71±1.66	33.26±2.26		
13″-18″	No nitrogen	134	15.22	2265	3183	1265	69.31±1.59	40.96±2.45	8.84±4.08	5:1
13″-18″	Nitrogen	117	15.38	2000	2795	882	69.95±1.47	32.12±3.27		
19″-24″	No nitrogen	55	21.36	1269	1877	718	73.54±1.12	37.76±1.96	6.76±3.70	3:1
19″-24″	Nitrogen	59	21.24	1293	1882	660	73.41±1.17	31.00±3.14		
25″-Up	No nitrogen	30	29.36	890	1325	451	72.80±1.46	34.97±1.98	3.71±2.75	2:1
25″-Up	Nitrogen	52	28.90	1514	2204	710	72.80±1.42	31.26±1.91		

was reduced on the shoots of all lengths as compared with the checks. Nitrogen applications had no effect on the formation of fruit buds when applied to summer-pruned trees. It is believed that summer-pruning stimulated tree growth and reduced the leaf area to such an extent that carbohydrates limited the formation of buds by the Salwey trees.

Hardiness of the Buds

The extent of winter-killing of the Greensboro fruit buds during the winter of 1925-26 seemed to be related to the growth of the trees during the previous growing season (Table 2). It appears that the conditions which promoted the growth of the trees caused the buds to be susceptible to winter-killing. The data of Table 2 show some striking relations between the severity of the pruning or nitrogen applications and the ability of the buds to withstand winter conditions. The trees producing the hardiest buds were the checks. When a four-pound application of nitrate of soda was made to similar trees the hardiness of the buds slightly decreased.

The trees pruned severely in the dormant season produced buds about as susceptible to injury from low temperatures as those which had received the lighter pruning and nitrate of soda. When nitrate of soda was applied to similarly heavily-pruned trees the buds were still more tender. One summer-pruning reduced the hardiness of the buds more than the heavy dormant pruning, and when nitrate of soda was applied they were less hardy. Continued summer pruning caused the buds to be very tender.

The degree of severity or the time of pruning apparently had a greater effect on the hardiness of the buds than the application of nitrogen. In some instances the differences in hardiness of the buds of the trees which did and did not receive nitrogen are not significant; in others, however, they are. When the hardiness of the buds of all the fertilized trees is compared with those not fertilized, the former were significantly more tender.

During the winter of 1926-27 studies on the hardiness of the Greensboro buds were confined to the effects of nitrogen applications. Very little injury to the buds occurred during the winter. Table 3 shows that the nitrogen applications caused the buds to be hardier than those on trees not fertilized. The differences are small and they are the exact opposite of what was found the previous winter. It would seem that this disagreement may be accounted for through the effects of the crop of fruit produced by the trees in the summer when the buds were formed.

The trees fertilized the previous year (1925) were larger in size and had darker green and healthier foliage than those not nitrated. The fertilized trees suffered greater injury to the fruit buds in the winter of 1925-26,with the result that there were less flowers to open and less fruit to set and mature per unit of wood than on the unfertilized trees.

TABLE 5.—*Influence of Length of Shoots and of Nitrogen Applications on Formation and hardiness of Greensboro Fruit Buds,* 1926-27

Length of Shoots	Treatment	Total No. of Shoots	Average Length of Shoots	Total No. Nodes	Total No. Buds Formed	Total No. Buds Alive After Last Freeze	Percentage of Buds Formed	Percentage of Buds Alive	Ratio: Buds Alive / 2 x No. of Nodes
0"- 6"	No nitrogen	98	3.316	711	838	760	58.93	90.69	.534
0"- 6"	Nitrogen	118	3.322	956	1017	959	53.19	94.29	.501
7"-12"	No nitrogen	55	9.854	850	1134	1018	66.70	89.77	.599
7"-12"	Nitrogen	43	9.674	725	883	841	61.09	95.24	.580
13"-18"	No nitrgoen	41	15.463	878	1429	1287	81.37	90.06	.733
13"-18"	Nitrogen	26	14.923	545	728	686	66.26	94.32	.625
19"-24"	No nitrogen	15	21.333	386	654	579	84.71	88.53	.750
19"-24"	Nitrogen	9	21.111	217	329	316	75.77	96.38	.730
25"-Up	No nitrogen	6	25.166	169	303	274	89.64	90.42	.810
25"-Up	Nitrogen	11	27.363	331	531	487	86.91	94.59	.825
Total all	No Nitrogen	215	9.172	2994	4358	3918	72.79	89.90	.654
Total all	Nitrogen	207	8.149	2774	3488	3289	62.86	94.29	.593

Little difference was indicated between the trees that received four or 16 pounds of nitrate of soda in the formation or hardiness of the fruit buds. The large amount of nitrate applied probably caused some root injury so that the nitrogen was not absorbed. This view is supported by the data for the total nitrogen and moisture content of the fruit buds, which will be considered later.

The response of the Salwey to pruning and applications of nitrogen was quite different from that of the Greensboro (Table 3). The check trees produced the hardiest buds, and when nitrogen was applied to similar trees there was an indication that the hardiness was slighty decreased. The buds of the trees that had been summer pruned were significantly more tender than those of the checks, and when nitrogen was applied to similar trees the buds were still less resistant. This is in agreement with the results for the Greensboro for the previous winter. The conditions that increased or prolonged the growth of the trees resulted in less hardy buds.

From the data presented it would seem that the conditions which promoted the growth of the trees either by a more rapid rate of growth or by a longer growing period caused the fruit buds to be susceptible to winter injury. The apparent exception of the Greensboro during the winter of 1926-27, following a crop, indicates that the production of fruit is an important factor in determining the hardiness of the buds.

Relation of Length of Shoot to the Formation and Hardiness of Fruit Buds

It may be deduced theoretically that the formation and the hardiness of the fruit buds should decrease with increasing length of the shoot on which they are borne. Casual field observations indicated this to be true. Accordingly studies were made as regards the number of fruit buds formed per node and the hardiness of these buds as affected by the conditions influencing the length of the shoot. For these studies the shoots were divided into the following classes: 0 to 6, 7 to 12, 13 to 18, 19 to 24, and 25 to 36 inches.

Fruit Bud Formation

The data for the winter of 1925-26 for Greensboro show that the short shoots, 0 to 6 inches, formed the smallest percentage of fruit buds, and the longest shoots, 25 to 36 inches, the highest (Table 4). There was little, if any, difference in the percentage of buds formed on shoots of the same length from trees that received nitrate of soda and from those that did not. The interesting fact brought out by the data is that in the case of the Greensboro, fruit-bud formation increased as the length of the shoots became longer, while the behavior of the Salwey, as will be shown later, was the opposite in this respect.

The percentage of fruit-bud formation on the Greensboro during the season of 1926-27 was again related to the length of the shoots on which they were borne (Table 5). When the node is taken as the

TABLE 6.—*Influence of Length of Shoots and of Nitrogen Applications on Formation and Hardiness of Salwey Fruit Buds, 1926-27**

Length of Shoots	Treatment	Total No. of Shoots	Average Length of Shoots	Total No. Nodes	Total No. Buds Formed	Total No. Buds Alive After Last Freeze	Percentage of Buds Formed	Percentage of Buds Alive	Ratio: Buds Alive / 2 x No. of Nodes
0″- 6″	Nitrogen	103	4.12	967	753	642	38.93	85.25	.339
0″- 6″	No nitrogen	118	4.37	1161	751	618	32.34	82.29	.266
7″-12″	Nitrogen	92	9.80	1627	1138	917	34.97	80.57	.282
7″-12″	No nitrgoen	97	9.50	1596	1058	862	33.14	81.47	.270
13″-18″	Nitrogen	59	15.12	1380	947	714	34.31	75.39	.259
13″-18″	No nitrogen	61	15.03	1437	855	654	29.74	76.49	.227
19″-24″	Nitrogen	47	21.04	1347	782	581	29.02	74.29	.216
19″-24″	No nitrogen	38	20.97	1068	502	375	23.50	74.70	.175
25″-Up	Nitrogen	23	27.69	791	448	278	28.31	62.05	.176
25″-Up	No nitrogen	15	26.86	495	217	162	21.91	74.65	.164
All	Nitrogen	324	11.867	6112	4068	3132	33.27	76.99	.256
All	No nitrogen	329	10.799	5759	3383	2671	29.38	78.95	.232

*The data presented in this table have been computed from rows 27, 29, and 31 only.

unit of comparison the short shoots formed the least and the longest shoots the most buds. Applications of nitrogen to the trees had a tendency to reduce the percentage of buds formed. In this connection it is well to point out that with a variety like Greensboro, the effect of nitrogen applications on the potential fruit-bearing of the trees is through its influence on the length of the shoots rather than by greater fruit-bud formation. This is true because the production of a large number of long shoots increases not only the bearing area of the trees but also the number of buds formed at each node.

TABLE 7.—*Coefficients of Correlation Between Length of Shoot and Formation and Hardiness of Greensboro Fruit Buds,* 1925-26

Characters Correlated	Coefficients of Correlation	
	No Nitrogen	Nitrogen
Percentage of buds formed with length of shoot	+.808± .047	+.784± .052
Percentage of buds alive with length of shoot	—.645± .079	—.319± .121

The short shoots of the Salwey formed the highest percentage of buds, and as the length of the shoots increased the percentage of fruit-bud formation became smaller (Table 6). This is the opposite of what was found to be true of the Greensboro, and shows a marked difference in these relationships between shoots of the same length of the two varieties under study.

Hardiness of the Buds

The buds on the short shoots of the Greensboro were significantly more resistant to freezing temperatures during the winter of 1925-26 than those borne on the long shoots (Table 5). Hardiness varied inversely with the length of the shoots on which the buds were borne. The effect of nitrogen applications was to reduce the hardiness of the buds on shoots of the same length. This was particularly true for buds of the short shoots but in the case of the long ones there was little difference in their resistance.

The data for the Greensboro for the winter of 1926-27 show no difference in the hardiness of the buds borne on long or short shoots (Table 6). The shoots of all lengths on trees that had been fertilized with nitrate of soda had a higher percentage of buds which survived the winter than similar classes of shoots from trees not fertilized. This circumstance may have been due to a larger crop of fruit borne per unit of bearing area on the trees not fertilized as compared to the ones that had received nitrogen.

The fruit buds borne on the short shoots of the Salwey were hardier than those on the long ones. From the data in Table 6 there is an indication that the tenderness of the buds was proportional to the length of the shoot on which they were borne. Nitrogen applications had little, if any, effect on the hardiness of the buds, as the differences in resistance of the buds borne on shoots of the same length, with or without nitrogen, are within the limits of experimental error.

These relations for the Greensboro during the winter of 1925-26 are more clearly brought out by Table 7, in which are given the

coefficients of correlation for the fruit-bud formation and hardiness of the buds as correlated with the length of the shoots on which they were produced. The percentage of fruit-bud formation was highly correlated with the length of the shoot on which the buds were borne; the coefficient of correlation without nitrogen was +.808 ±.047, and with nitrogen applications, +.784 ±.052. Hardiness of the buds was negatively correlated with the length of the shoots, the coefficients of correlation being —.645 ±.079 and —.319 ± .121, without and with nitrogen, respectively. The data given above and that to be presented later for the Salwey show that both fruit-bud formation and hardiness were negatively correlated with the length of the shoot.

Dry Weight of the Fruit Buds

Several investigations have shown that hardiness is related to a low water content of the tissue. From this and other considerations it was thought that pruning or nitrate of soda applications through stimulation of the growth of the trees would increase the water content of the buds and thus decrease their resistance to injury from freezing temperatures. To study the relations existing between the dry weight of the buds to the growth conditions under which the buds were formed, as well as the relation of their moisture content to their hardiness, the percentage of dry weight of the buds was determined at intervals throughout the winter by methods already described.

TABLE 9.—*Percentage of Dry Weight of Fruit Buds,* 1926-27

	Row	Treatment	Percentage of Dry Weight on Nov. 15	Dec. 17	Jan. 28
Greensboro	31	Check	49.930	51.743	49.244
	31	4 pounds of nitrate of soda	50.526	51.239	48.752
	29	No nitrogen	50.657	50.434	47.826
	29	16 pounds of nitrate of soda	51.068	50.070	48.361
Salwey	31	4 pounds of nitrate of soda	45.839	46.220	44.174
	31	Check	46.332	46.577	45.199
	27	Two summer prunings + 4 pounds of nitrate of soda	44.797	45.220	43.944
	27	Two summer prunings	44.894	45.226	44.753

Samples were taken three times during the winter of 1925-26 for dry weight determinations (See Table 8). The check trees had the highest percentage of dry weight on November 20 and retained this position throughout the winter. The summer-pruned trees had the lowest percentage of dry weight. For several days previous to December 17, the time of collecting the second lot of samples, the weather had been cold with the maximum temperatures ranging from 21° to 37°F. Samples taken at this time were lower in moisture than earlier. The buds with the lowest percentage of dry weight on November 20 made the greatest gain in dry matter, while the check or similar trees which had been fertilized and which had the highest

percentage of dry weight on the earlier date, lost the least water during the cold period.

The samples collected on January 19 were taken during another warm period. At this time the buds had increased in moisture so that their percentage of dry weight was approximately six percent less than that on December 17. The buds with the highest percentage of dry weight earlier in the season still maintained their relative position, and those from the summer-pruned trees which had the lowest dry weight still contained the most water. Nitrogen applications did not have any marked effect on the percentage of dry weights of the buds.

The differences in the percentage of dry weight of the buds from the various treatments of the Greensboro or Salwey were small during the winter of 1926-27 (Table 9). These small differences, not significant in some instances, indicate that the practices which promoted the growth of the trees during the previous growing season reduced the percentage of dry weight of the buds. There was a very significant difference between the buds of the two varieties in the percentage of dry weight as it was much higher throughout the winter in the hardy Greensboro than in the tender Salwey.

It would seem that the practices which accelerated the growth of the trees, or reduced the leaf area, or both, decreased the percentage of dry weight of the fruit buds of both varieties. These and other data to be presented show a fairly close relation between percentage of dry weight and hardiness of the buds.

Bound Water of the Fruit Buds

During the winter of 1925-26 the moisture content of the Greensboro fruit buds was found to be related to the vegetative vigor of the trees. In view of this relation it was thought that perhaps more of the water of the hardy buds was held tenaciously during freezing weather and was not given up to form ice so readily as with the more tender buds. This relation was studied during the winter of 1926-27, and the data are given in Table 10.

The Salwey fruit buds had not only a lower percentage of dry weight than those of the Greensboro (Table 9), but also a smaller percentage of water held tenaciously (Table 10). There was a smaller difference between the various treatments of the Greensboro in the amount of bound water than in those of the Salwey. The applications of nitrogen to the Salwey trees decreased the percentage of bound water of the buds, in some way, presumably through prolonged growth and carbohydrate utilization. Summer pruning apparently had little or no effect on the bound water of the buds.

It is not possible to draw conclusions regarding the relation of the water held tenaciously by the buds and their hardiness, on account of the small differences between treatments. There is some indication that the hardy buds contained more water which was less easily given up than from the tender buds.

TABLE 8.- *Influence of Pruning and Nitrogen Applications on Percentage of Dry Weight of Greensboro Fruit Buds*, 1925-26*

Row	Treatment	Percentage of Dry Weight			Gain in Dry Weight Percent	Loss in Dry Weight Percent
		Nov. 20	Dec. 17	Jan. 19	Nov. 20-Dec. 17	Dec. 17-Jan. 19
32	Heavy dormant pruning ...	46.63	49.03	42.78	2.40	6.25
32	Heavy dormant pruning ... + nitrogen	46.22	48.28	42.54	2.06	5.74
31	Check	50.60	51.80	45.59	1.20	6.21
31	Nitrogen	49.55	50.37	44.61	.82	5.76
25	1 summer pruning	48.28	51.06	44.76	2.78	6.30
25	1 summer pruning ..... + nitrogen	47.92	51.04	44.71	3.12	6.33
27	2 summer prunings	44.64	49.33	42.40	4.69	6.93
27	2 summer prunings ..... + nitrogen	45.32	48.99	42.91	3.67	6.08
29	3 summer prunings	46.58	49.10	42.45	2.52	6.65
29	3 summer prunings ..... + nitrogen	46.71	48.44	42.10	1.73	6.34

*Change in percentage of dry weight from November 20 to December 17 due to loss of water caused by freezing weather previous to collecting samples. Loss in percentage of dry weight from December 17 to January 19 due to the increase in water of the buds caused by their growth and the warm weather preceding the time of collecting samples.

TABLE 10.—*Percentage of Bound Water in Fruit Buds*, 1926-27

	Row	Treatment	December 17			January 28		
			Percentage of					
			Water Loss After 144 Hrs. at 30°C.	Water loss After Drying 72 Hrs. in Vacuo	Bound Water	Water Loss After 144 Hrs. at 30°C.	Water Loss After Drying 72 Hrs. in Vacuo	Bound Water
Greensboro	31	Check	46.016	48.255	2.239	48.691	50.755	2.064
	31	4 pounds nitrate of soda	46.535	48.759	2.224	49.237	51.247	2.010
	29	No nitrogen	47.473	49.566	2.093	50.386	52.173	1.787
	29	16 pounds nitrate of soda	47.819	49.928	2.109	49.678	51.638	1.960
Salwey	31	4 pounds nitrate of soda	51.806	53.777	1.971	54.132	55.825	1.693
	31	Check	51.413	53.421	2.008	52.875	54.800	1.925
	27	Two summer prunings + 4 pounds nitrate of soda	53.314	54.779	1.465	54.424	56.055	1.631
	27	Two summer prunings..	52.735	54.773	2.038	53.331	55.246	1.915

Size and Increase in the Dry Weight of the Fruit Buds

Since each bud is a unit, composed of the floral parts enclosed in a number of bud scales, the dry weight of 100 buds has been calculated for the samples taken at the different times during the winter. This was done to study: (a) the relation of the vegetative growth of the trees to the size or weight of the buds; (b) the relation of the growth of the trees to that of the buds as measured by their increase in dry weight during the winter months. These data for the winter of 1925-26 are given in Table 11. There is an indication that the treatments which promoted the growth of the trees caused the buds to be smaller at the time the first samples were taken than those not forced to grow so late. The check trees had the largest buds on November 20, and remained so to January 19. The heavy dormant pruning, summer-pruning, or nitrate of soda applications had reduced the size of the buds at the time the first samples were taken.

There was an appreciable increase in the dry weight of the buds from November 20 to January 19 (Table 11). The buds from the trees that had received the application of nitrate of soda made the greatest growth with the exception of the trees that had been pruned two or three times during the preceding summer. In the latter case the fruit buds from the trees not fertilized made the greatest growth. The summer-pruning reduced considerably the leaf area and at the same time stimulated the growth of the trees. Applications of nitrogen to these trees caused increased vegetative growth, and apparently the carbohydrates had been utilized during the summer and fall at the expense of the fruit buds.

In the fall of 1926 the Greensboro fruit buds borne on the trees fertilized with nitrate of soda were larger on November 15 than those from similar trees not fertilized (Table 12). By January 28, 1927, the fruit buds of the latter had grown until they were practically as large as those of the former, with the exception of the buds of the trees of Row 29. In this case apparently there has been cross feeding of the root systems of the trees not fertilized and probably root injury to those that received the 16 pounds of nitrate of soda, as is indicated by the moisture and nitrogen content of the buds. The results with the Greensboro are different from those of the previous winter in that the trees fertilized with nitrate of soda had the smallest buds at the beginning of winter and these grew more rapidly than those of the trees not fertilized.

The probable explanation for this difference in the growth of the buds is that the crop of fruit produced in the summer of 1926 altered the nutritional conditions so that the nitrogen trees with the larger leaf area were able to produce the crop and at the same time store more carbohydrates than those not fertilized. This difference in the growth of the buds during the winter apparently accounts for the greater hardiness of those borne on the trees that had been fertilized.

TABLE 11.—*Dry Weight of 100 Greensboro Fruit Buds*, 1925-26

Row	Treatment	Average Dry Weight of 100 Buds in Grams on				Increase from Nitrogen Application	Percentage of Increase Nov. 20 to Jan. 19
		Nov. 20	Dec. 17	Jan. 19	Increase		
32	Heavy dormant pruning ...	.597	.606	.645	.048	...	8.04
32	Heavy dorman pruning ... + nitrogen	.527	.571	.613	.086	.038	16.32
31	Check	.662	.641	.699	.037	...	5.59
31	Nitrogen	.643	.654	.707	.064	.027	10.00
25	1 summer pruning	.569	.653	.647	.078	...	13.71
25	1 summer pruning ..... + nitrogen	.559	.648	.670	.111	.033	19.85
27	2 summer prunings	.568	.655	.644	.076	...	13.38
27	2 summer prunings ..... + nitrogen	.592	.658	.653	.061	—.015	10.30
29	3 summer prunings	.582	.688	.668	.086	...	14.78
29	3 summer prunings ..... + nitrogen	.550	.616	.604	.054	—.032	9.82

TABLE 12.—*Dry Weight of 100 Fruit Buds*, 1926-27

	Row	Treatment	Average Dry Weight in Grams of 100 Fruit Buds on:				Percentage of Increase Nov. 15 to Jan. 28
			Nov. 15	Dec. 17	Jan. 28	Increase from Nov. 15 to Jan. 28	
Greensboro	31	Check	.642	.774	.806	.164	25.57
	31	4 pounds nitrate of soda	.675	.768	.797	.122	18.09
	29	No nitrogen	.643	.743	.765	.122	18.91
	29	16 pounds nitrate of soda	.660	.776	.801	.141	21.35
Salwey	31	Check	.554	.640	.700	.146	26.35
	31	4 pounds nitrate of soda	.559	.692	.770	.211	38.01
	27	2 summer prunings	.536	.588	.625	.089	16.60
	27	2 summer prunings + 4 pounds nitrate of soda	.550	.648	.679	.129	23.54

There was little difference in the size of the Salwey buds from the trees of the various treatments on November 15 (Table 12). It would seem that the two summer prunings reduced the size of the buds and retarded their growth during the winter. Nitrogen applications caused the buds to be larger and increased the amount of growth they made from November 15 to January 28. The buds of the Salwey were considerably smaller than those of similar Greensboro trees.

It appears that the practices, pruning or nitrate applications, which stimulated the growth of the trees or prevented the accumulation of food materials, through growth or production of fruit, reduced the weight of the buds at the approach of winter. There is a strong indication that the buds on the more vegetative trees which made greater gains in dry weight during the winter months than the buds on the less vegetative trees were due, in part, to the relatively high water content of the vigorous buds. The data presented show that there was a negative correlation between the increase in dry weight of the buds and their hardiness.

Percentage of Total Nitrogen in the Fruit Buds

In some earlier work *(20)* on the influence of nitrate of soda on peach trees it was shown that application of nitrate decreases the hardiness of the fruit buds. It was also shown that there are residual effects from the nitrogen the following year. These results give weight to the idea that buds high in nitrogen are susceptible to injury from freezing temperatures. To study the effect of pruning and nitrate of soda applications on the nitrogen content of the buds and the relation of the latter to hardiness, total nitrogen determinations were made of the buds from the various treatments during the winters of 1925-26 and 1926-27. These data are given in Tables 13 and 14.

In general, the buds that were high in percentage of dry weight were low in percentage of total nitrogen, while those low in dry weight were high in total nitrogen. In other words, there seems to be a close relation between the moisture and nitrogen content of the buds. The data for the total nitrogen content of the buds at intervals through the winter of 1925-26, expressed in percentage of the dry weight of the fruit buds, are given in Table 13. These data show that during the winter there is a steady increase in the percentage of total nitrogen of the buds, as it was the lowest in November and the highest in January.

Pruning was a more important factor in determining the nitrogen content of the buds than was the application of nitrate of soda. The check trees had the lowest percentage of nitrogen in the buds at the time the first samples were taken and retained this position through the winter. The trees which were pruned heavily in the dormant season or which were summer-pruned had a high percentage of total nitrogen content of the buds. However, the buds from the trees which had been summer-pruned two or three times and had been fertilized were little different from those of similar trees not fertilized. A con-

TABLE 13.—*Total Nitrogen in Greensboro Fruit Buds*, 1925-26

Row No.	Treatment	Percentage* of Total Nitrogen on			Total nitrogen in 1000 Buds in Grams			Increase in Nitrogen Nov. 20-Jan. 19	Odds
		Nov. 20	Dec. 17	Jan. 19	Nov. 20	Dec. 17	Jan. 19		
32	Heavy dormant pruning	1.770	1.685	1.879	.1057±.0033	.1021	.1214±.0005	.0157±.0033	752:1
32	Heavy dormant pruning + nitrogen ...	2.024	2.026	2.087	.1067±.0009	.1158	.1280±.0096	.0213±.0096	6:1
31	Check	1.546	1.723	1.869	.1024±.0082	.1104	.1307±.0017	.0283±.0084	40:1
31	Nitrogen	1.747	1.870	1.957	.1124±.0097	.1224	.1385±.0025	.0261±.0100	12:1
25	1 summer pruning	1.632	1.787	1.848	.0929±.0035	.1168	.1196±.0032	.0267±.0047	7836:1
25	1 summer pruning + nitrogen....	1.707	1.765	1.949	.0955±.0034	.1144	.1307±.0097	.0352±.0103	45:1
27	2 summer prunings	2.001	1.971	2.011	.1138±.0134	.1291	.1297±.0014	.0159±.0135	1:1
27	2 summer prunings + nitrogen....	1.819	1.811	1.969	.1078±.0013	.1193	.1286±.0045	.0208±.0047	351:1
29	3 summer prunings	1.780	1.845	2.002	.1037±.0019	.1271	.1339±.0013	.0302±.0023	almost unlimited
29	3 summer prunings + nitrogen....	1.801	1.817	2.016	.0991±.0022	.1121	.1218±.0033	.0227±.0040	7727:1

*Dry weight basis.

TABLE 14.—*Total Nitrogen in Greensboro and Salwey Fruit Buds*, 1926-27

	Row	Treatment	Percentage* of Total Nitrogen on:			Total nitrogen in 100 Buds in Grams			Increase Nov. 15-Jan. 28	Odds
			Nov. 15	Dec. 17	Jan. 28	Nov. 15	Dec. 17	Jan. 28		
Greensboro	31	Check	1.508±.035	1.547	1.563±.019	.0967±.0018	.1197	.1282±.0025	.0315±.0032	Almost unlimited
	31	4 pounds nitrate of soda	1.598±.045	1.651	1.692±.023	.1133±.0038	.1267	.1348±.0029	.0215±.0048	396:1
	29	No nitrogen	1.815±.009	1.841	1.879±.016	.1196±.0009	.1368	.1438±.0024	.0242±.0026	Almost unlimited
	29	16 pounds nitrate of soda	1.736±.042	1.709	1.784±.033	.1193±.0035	.1355	.1430±.0014	.0237±.0038	38,758:1
Salwey	31	Check	1.872±.035	1.896	1.925±.024	.1038±.0028	.1212	.1349±.0052	.0311±.0059	2,644:1
	31	4 pounds nitrate of soda	2.097±.049	2.121	2.186±.037	.1121±.0027	.1469	.1527±.0026	.0406±.0037	Almost unlimited
	27	2 summer prunings	1.946±.050	2.072	2.152±.069	.1151±.0093	.1297	.1345±.0053	.0194±.0107	4:1
	27	2 summer prunings + 4 pounds nitrate of soda	2.233±.009	2.313	2.384±.029	.1228±.0029	.1499	.1622±.0049	.0394±.0057	321,336:1

*Dry weight basis.

siderable part of the nitrogen that was available to the fertilized trees probably had been used up in the growth of the trees, so that at the beginning of dormancy less of this material was stored than in the case of the trees not fertilized.

During the winter 1926-27 it was again found that applications of nitrate of soda made at the beginning of the previous growing season increased the percentage of total nitrogen in the buds as compared to similar ones not fertilized. The data of Table 14 would suggest that the unfertilized trees of Row 29 had been cross-feeding in the fertilized areas, as the buds of these trees had a higher nitrogen content than those from the fertilized trees.

TABLE 15.—*Coefficients of Correlation Between Moisture, Total Nitrogen, and Hardiness of Greensboro Fruit Buds,* 1925-26

Characters Correlated	Coefficients of Correlation
Total moisture of the buds with their total nitrogen content	+.408±.106
Increase in dry weight of the buds from Nov. 20 to Jan. 19 with the percentage of total nitrogen	+.616±.079
Increase in dry weight of the buds from Nov. 20 to Jan. 19 with the percentage of total moisture	+.386±.108
Increase in dry weight of the buds from Nov. 20 to Jan. 19 with the precentage of buds alive	—.511±.094
Percentage of buds alive with their total moisture content	—.864±.032
Percentage of buds alive with their total nitrogen content	—.679±.068

Summer-pruning increased the percentage of total nitrogen in the buds of the Salwey. The buds of these trees were the highest in nitrogen at the beginning of dormancy and remained so throughout the winter. The buds of both varieties increased in total nitrogen during the winter, as they were lowest in nitrogen in the fall and the percentage became greater as the winter advanced. The fruit buds of the Salwey contained a significantly larger percentage of total nitrogen than those of the Greensboro. The buds of the Salwey contained about three percent more water than those of the Greensboro, and in total nitrogen there is still a greater difference between the varieties.

To show more clearly the relations existing between moisture, nitrogen, increase in dry weight, and hardiness of the buds of Greensboro, coefficients of correlation have been calculated and are given in Table 15 for the winter of 1925-26. The moisture content of the buds was positively correlated with the percentage of total nitrogen. Likewise, the growth of the buds as measured by the increase in dry weight was significantly and positively correlated with their total nitrogen and moisture content. The percentage of buds that came through the winter uninjured was found to be negatively correlated with their gain in dry weight, with the total nitrogen content, and with the total moisture content of the buds. The coefficients of correlation are —.511±.094, —.679±.068, and —.864±.032, respectively. The data for the Salwey indicated that these relations also hold for this variety. The wide differences in dry weight and total nitrogen between the Greensboro and Salwey are closely related to the hardiness of the buds of these two varieties.

Total Nitrogen in One Thousand Fruit Buds

It has been demonstrated that nitrates influence the growth and hardiness of peach buds and theoretically there are good reasons for expecting such results. Since few data are available on this aspect of the problem the actual nitrogen content of the buds was determined. Furthermore, the gain in total nitrogen of the buds during the winter months would be a measure of their growth or of the movement of nitrogen into them. For these reasons the total nitrogen contained in 1,000 fruit buds has been calculated, and the data are given in Tables 13 and 14. There is an indication that during the winter of 1925-26 the buds from the trees not fertilized with nitrate contained less total nitrogen, although they were larger in size, than the ones from the fertilized trees (Table 13). All of the buds increased in total nitrogen from November 20 to January 19. The buds from the unfertilized trees made the most significant increase in total nitrogen during this period, excepting those from the trees which had been summer-pruned two or three times.

The increase in total nitrogen in the fruit buds was much more significant for the winter of 1926-27 than for the previous one (Table 14). These data show that the treatments which promoted the growth of the trees increased the amounts of total nitrogen in the buds. The buds from the checks or from trees that had not been fertilized were lower in total nitrogen from November 15 to January 28 than those from similar trees which had received nitrate of soda. During this period there was a very significant increase in the amounts of total nitrogen in the buds of the trees of all treatments, excepting one, which was probably due to error. The buds from the Greensboro trees not fertilized made the most significant increase in total nitrogen, while the opposite was true of similar trees of the Salwey.

It seems that the increase in total nitrogen was associated with the growth of the fruit buds, as the gain in dry weight follows closely that of nitrogen. It should be pointed out that the Salwey buds, although of smaller weight, contained as much or more total nitrogen than those of the hardy Greensboro.

Composition of the Fruit Buds

The data presented have shown that hardiness is associated with a low water and total nitrogen content of the fruit buds. The growth of the buds as measured by the increase in dry weight and gain in total nitrogen was found to be related to the vegetative conditions of the trees. The practices that stimulate the growth of the trees influence not only the amounts of carbohydrates used in growth but also the quantities stored. In view of these facts and in the belief that there might be some relation between carbohydrate storage and the growth and hardiness of the buds, analyses were made of samples collected from trees under the various treatments, on January 28, 1927. These data are given in Table 16.

Summer-pruning or nitrogen applications had little effect on altering the composition of the fruit buds within the variety. It is

expected that greater differences would have been found had analysis been made of the bark or wood on which the buds were borne, since these serve as storage tissues. The data of Table 16 show a wide difference between the buds of the two varieties, Greensboro and Salwey, in the percentage of reducing sugars, total sugar and starch, as well as moisture and total nitrogen. It seems reasonable to assume that the larger amounts of reducing and total sugars of the Salwey buds were associated with the greater growth response of this variety. The Salwey fruit buds contained approximately twice the percentage of starch as those of the Greensboro.

Applications of nitrate of soda or summer-pruning had no effect on the percentage of sugars or starch found in the buds. There was considerable difference between the two varieties in the percentage of alcohol-soluble non-sugars present, and the larger amounts were found in the buds of the hardy Greensboro. Applications of nitrate of soda seemed to have some effect on the percentage of alcohol-soluble non-sugars, as a comparison between these materials and the percentage of total nitrogen shows that the buds with a low nitrogen content had a larger amount of the former present. It seems that nitrogen applications caused a greater reduction in the percentage of alcohol-soluble non-sugars in the buds of the Salwey than in those of the Greensboro.

It would seem that the reserve food materials of the Greensboro are largely in forms not readily available for growth. The Salwey buds contained the largest quantities of soluble food materials and the smallest amounts of alcohol-soluble non-sugars and made the greatest response, as will be shown later. The growth of the buds was, apparently, the result of the nutritional conditions—a high sugar, water, and total-nitrogen content.

DISCUSSION

Greensboro and Salwey have been shown to differ greatly in respect to the formation of fruit buds. With the former variety there was a high and positive correlation between the percentage of fruit-bud formation and the length of the shoots on which they were borne, while with Salwey the opposite was true. It follows then that the practices that cause the production of long shoots increase fruit-bud formation on the Greensboro and reduce it on the Salwey. When shoots of the same length are considered, dormant or summer-pruning had no effect on the formation of fruit buds on the Greensboro. Fertilization with nitrate of soda had effects similar to that of pruning, except in the year that a crop of fruit was borne, when the percentage of buds formed was reduced on the shoots of all lengths of this variety. Summer-pruning decreases and nitrogen applications increase fruit-bud formation on the shoots of all lengths of the Salwey.

Dormant or summer-pruning has been shown to reduce the resistance of peach buds to low temperatures. Applications of nitrate

TABLE 16.—*Effect of Pruning and Nitrogen Applications on Carbohydrate and Nitrogen Content of Greensboro and Salwey Fruit Buds. Samples Taken January 28, 1927*

Row	Treatment	Percentage of Dry Weight of: Reducing Sugar as Glucose	Non-reducing Sugar as Glucose	Total Sugar as Glucose	Alcohol-soluble Non-Sugars	Starch	Hemicellulose	Total Nitrogen	Moisture Percent
				GREENSBORO					
31	Check	2.96	1.69	4.65	11.50	2.34	....	1.563	50.75
31	4 pounds of nitrate of soda	3.38	1.74	5.12	8.04	2.96	14.10	1.692	51.25
29	No nitrogen	2.90	2.64	5.54	9.64	2.94	13.02	1.879	52.15
29	16 pounds of nitrate of soda	2.38	2.74	5.12	10.77	2.75	12.05	1.784	51.82
				SALWEY					
31	Check	5.55	2.48	8.03	7.69	4.54	11.38	1.925	54.79
31	4 pounds of nitrate of soda	4.73	2.57	7.30	2.78	5.91	11.63	2.136	55.82
27	Two summer prunings	5.48	1.56	7.04	9.68	5.72	11.54	2.052	55.23
27	Two summer prunings + 4 pounds of nitrate of soda	4.83	2.46	7.29	5.39	...	10.06	2.384	56.01

of soda had effects similar to that of pruning on the hardiness of the buds, except during the winter of 1926-27, when the buds on the nitrated Greensboro trees were more resistant than the unfertilized ones. This was due probably to the crop of fruit produced the previous summer. The writer *(20)* has reported that fertilization with nitrate of soda causes the fruit buds to be tender and that the degree of susceptibility to injury is in relation to the amounts applied. These horticultural practices stimulate tree growth in two ways: by increasing the rate of growth, and by prolonging the growing period. As a result of the more vegetative condition of the trees, longer shoots and more of them are produced. The buds borne on the long shoots are more tender than those of the short ones. A fairly high degree of negative correlation exists between the length of the shoots and the hardening of the buds of both varieties.

It has been observed by growers in years of severe winter injury to peach buds that the bulk of the crop is produced on the short shoots which resemble spurs, and the balance by the buds borne at the base of the longer shoots. Craig *(19)* has reported that in Canada some varieties of peaches may have their terminal shoots killed back each year, yet will produce fruit generally upon the spurs situated on the older wood. It follows that the more the trees are forced to grow, the more tender the buds will be because of the longer shoots if for no other reason. It seems permissible then to draw the conclusion that the conditions which cause some shoots to grow long and others to grow short have an effect on the hardiness of the buds.

The nutritional conditions that have been associated with growth are a high moisture and nitrogen content in proportion to the carbohydrates, or a narrow carbohydrate-nitrogen ratio. Pruning or nitrogen application increases the percentage of moisture and nitrogen contained in the buds. There is a fairly high degree of negative correlation which exists between hardiness and moisture and the nitrogen content of the buds.

The amount of injury to the buds would appear to be related to the growth made the previous growing season by the trees and this is associated with the water and nitrogen made available by pruning or nitrogen applications, or both. Not only is the production of wood by the trees increased by these practices, but also the growth of the buds as measured by their gain in total nitrogen and dry matter during the winter months. It has been shown that there is a significant positive correlation between the nitrogen or moisture content of the buds and their growth during the winter, and that the increase in the dry weight of the buds is negatively correlated with hardiness.

The buds of the Salwey have been found to contain a larger percentage of reducing sugars, total sugar, and starch than those of the Greensboro, while the buds of the Greensboro are high in alcohol-soluble non-sugars and hemicellulose. It appears that the food reserves of the Greensboro are less available for growth than are those of the Salwey, and this, in a measure, may account for the difference in growth and hardiness of the buds of the two varieties.

PART II

The Influence of Ringing and Nitrogen Applications on the Formation, Composition, Growth, and Hardiness of Fruit Buds

Ringing has been shown by many experiments to reduce growth and to increase fruit-bud formation. Chandler *(16)* has pointed out that the sap concentration of the roots of ringed peach trees was less than that of similar ones not girdled. The work of Curtis *(24)* and Harvey *(44)* showed that ringing reduced the nitrogen and caused an accumulation of carbohydrates above the ring. As the growth and nitrogen content are reduced by ringing and as carbohydrates accaccumulate, these conditions theoretically should result in increased fruit bud formation and hardiness.

The hardiness of the buds may be influenced in two ways: (a) due to the accumulation of carbohydrates the sap concentration would be increased as shown by Chandler *(16)* and Curtis *(24)* and as a result there would be a greater quantity of complex carbohydrates and hydrophyllic colloids, causing greater retention of water against the drying forces of freezing than would be true of more vegetative tissue; (b) the accumulation of carbohydrates would perhaps increase the length of the rest period as suggested by Howard *(52)* and Abbott *(1)*.

In order to study the effects of ringing on the formation, composition, growth, and hardiness of peach fruit buds the following treatments were used.

Treatments

In these experiments the main scaffold limbs were ringed by removing a strip of bark about one-fourth inch wide from around the limb. Care was taken to see that all of the phloem was removed at the time of ringing. After the bark was removed the wound was immediately covered with grafting wax. The previous and subsequent treatments of the trees used as well as the time of ringing may be summarized as follows:

Row 27. Greensboro: 1925, Light dormant and two summer prunings. 1926, Corrective pruning. 1927, Corrective pruning and all of the main limbs on each tree ringed on June 20.

Row 28. Greensboro: 1925, Heavy dormant pruning. 1926, Corrective pruning. 1927, Corrective pruning and one main limb on each tree ringed on June 20.

Row 29. Salwey: 1925, Light dormant and three summer prunings. 1926 and 1927, Corrective pruning and all limbs on each tree ringed on June 11, 1926, and June 21, 1927.

Row 30. Salwey: 1925, Heavy dormant pruning. 1926 and 1927, Corrective pruning and half of all of the limbs on each tree ringed on June 11, 1926, and June 21, 1927.

Row 31. Greensboro and Salwey: 1925, Light dormant pruning. 1926 and 1927, no treatment. These trees were used as the checks.

The severity and type of pruning given was the same as that described in Part I. Each spring a standard 4-pound application of nitrate of soda was applied at the time of blooming to every other tree in all rows.

EXPERIMENTAL RESULTS

In these studies the effects of ringing and the application of nitrate of soda on the growth response of the trees has been observed. The influence of these practices on the dry weight, bound water, total nitrogen, and carbohydrate content of the buds has been determined. The changes in dry weight and total nitrogen content of the buds have been followed through one winter. The growth of the buds as measured by their increase in dry weight, gain in total nitrogen, gain in diameter of the naked buds and the development of the pollen during the winter months has been followed. These various phases of the problem will be considered in detail.

Growth Response

Within a short time, one to two weeks, after the limbs had been ringed, all terminal growth ceased, and terminal buds were formed. By the end of a month the leaves had taken on a yellow color which became deeper and finally, in late fall, changed to a deep reddish-orange. The bark likewise changed color and in late fall the shoots of the ringed limbs were a bright to a deep red. This was particularly noticeable with the shoots of the Salwey which are normally a brownish-green color. The development of bright pigments in the leaves and bark indicates the accumulation of sugar and the formation of complex compounds of high molecular weight. Not only was the change in color evident but the shoots produced on the girdled limbs were much more stocky: i. e., they were larger in diameter in proportion to their length than those borne on similar limbs not ringed. Leaf fall took place on the girdled Salwey and the normal Greensboro trees at about the same time. The leaves on the ringed limbs were shed in advance of those of the normal trees of the same variety.

Marked differences were observed in the time of blooming of the trees in the various treatments in the spring of 1928. The check trees of the Salwey bloomed about two days earlier than similar ones of the Greensboro. Of the treatments under consideration the blossoms first to open were on the trees that had received only nitrate of

soda; then in order of blooming were the checks and finally the trees that had been ringed.

The ringed trees bloomed about a week to ten days later than the check trees. The development of the flower and leaf buds was retarded in all cases by the ringing. At bloom the normal order of the opening of the flowers of both varieties was reversed: i. e., the buds at the base of the shoots on the ringed limbs opened first, and blooming proceeded toward the terminals. The check and fertilized trees of both varieties bloomed normally. No explanation for this reversal in the normal activities of the ringed trees can be given. The explanation will probably be found in a change in the normal distribution of water, nitrogen, and food materials to the buds on the different parts of the shoot.

Formation and Hardiness of the Fruit Buds

In Tables 17 and 18 are given the data for the formation and hardiness of the fruit buds as influenced by ringing and nitrate of soda applications. In both years the trees probably were ringed too late in the growing season for this practice to have much effect on the formation of fruit buds.

Formation of Fruit Buds

The data for the winter of 1926-27 show that nitrogen applications increased the percentage of fruit buds formed (Table 17). In some instances the increase in fruit-bud formation following the nitrogen applications was small but significant. In no case did ringing increase the formation of fruit buds over that of the checks. Perhaps the most striking results from the different treatments on the formation of fruit buds were those obtained when half of the limbs of the trees were ringed and the others left normal (Row 30). Nitrogen applications had no effect on the percentage of buds formed on the ringed halves of these trees; neither did it have any influence on the normal limbs of the same trees.

The percentage of fruit-bud formation on the normal limbs was greatly reduced when some of the limbs on the same trees were ringed. Girdling half of the limbs on a tree not only disturbed the nutritional conditions above the ring but affected the limbs not girdled, as fewer buds were formed, and these were more tender than those of the checks. These and other data to be presented later indicate that ringing half of the main limbs of a tree and leaving the others normal affects both sides of the tree.

There would seem to be little question but that ringing half of the branches of the trees prevented to some extent the upward movement of nitrogen, and as a result the limbs not girdled received that which normally would have been used throughout the entire tree tops. This increased nitrogen that was available to the limbs not ringed apparently produced nutritional conditions very similar to that caused by two summer prunings (Part I), which resulted in reduced fruit bud formation. In this case it would seem that there had been

TABLE 17.—*Formation and Hardiness of Salwey Fruit Buds as Influenced by Ringing and Nitrogen Applications,* 1926-27

Row	Treatment	Total No. of Shoots	Total Length of Shoots	Total No. of Nodes	Total No. of Buds Formed	Total No. of Buds Alive After Last Freeze	Average Percentage of Buds Formed	Average Percentage of Buds Alive
30	Ringed } Limbs on the	106	1069	1779	1255	1012	35.17±1.35	80.97±2.24
30	Not ringed } same trees	106	1486	2139	909	687	21.22±1.25	75.24±1.90
30	Ringed+nitrogen } Limbs on the	110	952	1470	1281	1046	36.82±0.80	81.65±0.07
30	Not ringed+ nitrogen } same trees	110	1539	2180	972	727	22.37±0.59	74.61±1.45
31	Nitrogen	108	1393	1979	1420	1099	35.98±1.37	77.50±1.74
31	Check	111	1261	1945	1182	963	30.43±0.45	81.39±1.66
29	Ringed+nitrogen	108	1123	1953	1480	1197	37.90±0.75	80.95±1.48
29	Ringed	110	1171	1964	1263	996	32.17±1.12	78.72±1.34

TABLE 18.—*Influence of Ringing and Nitrogen Applications on Formation and Hardiness of Peach Buds,* 1927-28

Variety	Row	Treatment	Total No. of Shoots	Average Shoot Length	Total No. of Nodes	Total No. of Buds Formed	Total No. of Buds Alive After Last Freeze	Total No. Buds With Pistils Killed	Percentage of Buds Formed	Percentage of Buds Formed	Percentage of Buds With Pistils Killed	Percentage of Buds Alive + Percentage of Buds with Pistils
Greensboro	31	Check	111	5.90	1287	1838	1488	13	71.41	80.96	.71	81.67
	31	Nitrogen	111	6.71	1331	1928	1553	59	72.43	80.55	3.06	83.61
	28	Not ringed*	36	5.78	408	581	481	20	71.20	82.79	3.44	86.23
	28	Ringed*	36	4.75	385	550	485	14	71.43	88.18	2.54	90.72
	28	Not ringed + nitrogen*	36	6.64	431	606	506	26	70.30	83.50	4.29	87.79
	28	Ringed + nitrogen* ..	72	6.15	829	1234	1101	24	74.43	89.22	1.94	91.16
	27	Ringed	74	5.72	786	1203	1147	0	76.53	95.34	0	95.34
	27	Ringed + nitrogen* ..	74	6.32	853	1354	1263	0	79.37	93.28	0	93.28
Salwey	31	Check	108	6.19	1602	988	424	189	30.84	42.91	19.13	62.04
	31	Nitrogen	108	7.08	1673	1201	591	62	35.89	49.21	5.16	54.37
	30	Not ringed*	35	6.66	463	283	140	63	30.23	49.47	22.26	71.73
	30	Ringed*	37	6.19	475	346	215	40	36.42	62.14	11.56	73.70
	30	Not ringed + nitrogen*	35	7.86	498	364	209	35	36.55	57.42	9.62	67.04
	30	Ringed + nitrogen* ..	35	5.85	450	328	202	24	36.44	61.59	7.32	68.91
	29	Ringed	74	6.85	980	667	341	100	34.03	51.12	14.99	66.11
	29	Ringed + nitrogen ..	74	7.58	1041	843	591	34	40.49	70.11	4.03	74.14

*Limbs on the same trees.

radial translocation of some of the nitrogen at least, and in this respect these results do not agree with those of Auchter *(6)*, who found that nitrogen taken up by the roots on one side of the tree goes to the corresponding side of the tree top.

The results for the year 1927-28 were very little different from those of the previous one (Table 18). When all of the limbs on the trees were ringed, fruit-bud formation was slightly increased on both varieties. Ringing certain limbs on a tree had little or no effect on the formation of fruit buds on either the ringed or normal branches of either variety. Nitrogen applications likewise had little or no effect on fruit-bud formation. The slight effect of ringing on the formation of the fruit bud may be explained in one of two ways: either it had probably been initiated before the trees were ringed, or it was done too late to affect sufficiently the carbohydrate-nitrogen relations before fruit-bud initiation.

Hardiness of the Buds

The fruit buds borne on branches ringed during the previous June were no hardier during the winter of 1926-27 than were those of the checks, except when nitrogen was applied (Table 17). It has been pointed out previously that in the winter of 1927-28 a minimum temperature of 23°F. on March 17 killed a rather large percentage of the pistils of the fruit buds of the Salwey and a few of the Greensboro. It is not known whether only pistils or, in some cases, the entire buds were killed at this time. The data are unusual and to the writer's knowledge no similar case has been reported.

The effect of the nitrogen applications made at the time of blooming in the spring of 1927 on the hardiness of the Salwey buds during the winter of 1927-28 is clear in so far as the fertilized trees had the largest percentage of live buds (Table 18). Ringing a part of the entire tree increased the percentage of buds of both varieties which came through the winter uninjured. The application of nitrogen to the girdled trees also resulted in still greater hardiness of the buds. Ringing all of the branches of a tree was more effective in increasing the hardiness of the buds than when only a part of the limbs were girdled. This difference probably was due to the low moisture and nitrogen content of the buds of the ringed limbs, as will be shown later.

An examination of the data reveals that applications of nitrogen to the Salwey trees resulted in injury from cold to the pistils of the buds. It has been shown that fertilization with nitrogen or pruning increases the nitrogen content of the buds and that this is negatively correlated with hardiness. The lack of hardiness in the buds of high nitrogen content has been shown to be due to the growth of the buds as measured by the gain in dry weight and total nitrogen during the winter months. Then the explanation for the resistance of the buds which received nitrate of soda seems to be that they were ad-

vanced in their development and had passed the stage when the pistils were most susceptible to injury, or they were less active vegetatively at the time of the low temperature in March. The former explanation seems the most probable in view of data to be presented later.

In the case of the Greensboro, pistil killing was very slight, but there was some indication that fertilization caused the buds to be susceptible to this injury. This would seem to be opposed to the explanation just offered for the Salwey. It will be shown later that during the winter the buds of the Greensboro were much less advanced in their development than the Salwey. Hence if fertilization of the Greensboro accelerated the development of the buds, they were, in this instance, in a stage more susceptible to injury than those on similar trees not fertilized.

The amount of injury to the buds of the two varieties in both winters perhaps was not sufficiently severe to bring out the difference in hardiness that would appear to have existed between the various treatments.

TABLE 19.—*Influence of Length of Shoots and of Ringing with and without Nitrate of Soda Applications on Formation and Hardiness of Salwey Fruit Buds*, 1926-27*

Length of Shoots	Total No. of Shoots	Average Shoot Length	Total No. of Nodes	Total No. of Buds Formed	Total No. of Buds Alive After Last Freeze	Percentage of Buds Formed	Percentage of Buds Alive
RINGED + NITROGEN							
0"- 6"	52	4.07	517	383	333	37.04	86.94
7"-12"	33	9.69	575	424	346	36.86	81.60
13"-18"	18	14.16	419	303	245	36.15	80.85
19"-24"	4	20.50	130	106	79	40.76	74.52
25"-Up	3	27.66	99	65	43	32.82	66.15
NOT RINGED + NITROGEN							
0"- 6"	27	4.18	259	147	126	28.37	85.71
7"-12"	28	9.18	412	203	170	24.63	83.74
13"-18"	24	14.75	527	208	161	19.73	77.40
19"-24"	14	21.64	387	135	90	17.44	66.66
25"-Up	17	30.11	595	279	180	23.44	64.61
RINGED, NO NITROGEN							
0"- 6"	37	4.75	389	270	219	34.70	81.11
7"-12"	40	9.40	651	476	389	36.55	81.72
13"-18"	18	14.88	414	282	231	34.05	81.91
19"-24"	8	21.00	229	158	122	34.49	72.21
25"-Up	3	27.00	96	69	51	35.93	73.91
NOT RINGED, NO NITROGEN							
0"- 6"	21	4.66	225	108	84	24.00	77.77
7"-12"	35	9.02	528	273	217	25.85	79.48
13"-18"	25	15.84	568	244	187	21.47	76.63
19"-24"	8	21.12	224	72	48	16.07	66.66
25"-Up	17	29.82	594	212	151	17.84	71.22

*Data for Row 30 only. One-half of the main limbs on each tree were ringed on June 11, 1926.

Relation of Length of Shoot to the Formation and Hardiness of Fruit Buds

In order to study certain relationships, the data of Row 30 have been separated into four groups according to treatment: ringed plus nitrogen, not ringed plus nitrogen, ringed and no nitrogen, and, not ringed and no nitrogen. The data have been further divided into five classes, according to the length of the shoots. These data for the Salwey for the winter of 1926-27 are given in Table 19. Ringing half of the main limbs of the trees during June was found to increase the percentage of fruit buds formed on the shoots of all lengths as compared to the formation of buds on the same trees but on branches that had not been girdled.

TABLE 20.—*Coefficients of Correlation for Formation and Hardiness of Fruit Buds as Correlated with Length of Shoot on Which the Buds were Borne,* 1927-28

Characters Correlated	Coefficient of Correlation	
	Salwey	Greensboro
Percentage of buds formed with length of shoot	—.712±.048	+.856±.029
Percentage of buds alive with length of shoot	—.482±.075	—.597±.069

The striking relation brought out by the data of Table 19 is that ringing increased fruit-bud formation on the long shoots so that they formed approximately the same percentage of buds as did the short ones. The hardiness of the buds on shoots of the same length was not influenced by ringing or nitrate of soda applications. Hardiness was related to the length of the shoot on which the buds were borne, as the hardiness of the buds decreased as the length of the shoot increased.

Detailed data for the winter of 1927-28 are not included for the reason that they are little different from that given in Part I. The trees were probably ringed too late in the summer of 1927 for the ringing to have any appreciable influence on the formation of fruit buds. Coefficients of correlation have been calculated for the formation and hardiness of the buds with the length of the shoot on which they were produced, and these are given in Table 20. In calculating the coefficients of correlation all of the data for the season, for each variety, have been included. Thus the data do not show the difference in fruit-bud formation or hardiness of the buds due to treatment but simply the general behavior of the varieties. This has been done because it was thought unnecessary to distinguish between treatments, since the growth conditions that produced long shoots caused the buds to be tender.

The hardiness of the buds of both varieties was negatively correlated with the length of the shoots. The coefficients of correlation between the length of the shoots and the percentage of buds alive for the Salwey and Greensboro are: —.482±.075 and —.597±.069, respectively. The formation of fruit buds on the Salwey was negatively, and on the Greensboro positively, correlated with the length of the shoot. These coefficients are —.712±.048 and +.856±.029, respectively.

Dry Weight of the Fruit Buds

It has been shown that the practices which increased the growth of the trees decreased the percentage of dry weight of the fruit buds (Part I). To study the effects of ringing and of nitrate of soda applications on the percentage of dry weight of the fruit buds, samples of buds from the various treatments were taken three times during the winter of 1926-27 and once in the winter of 1927-28. These data are given in Tables 21 and 22. Ringing slightly increased the percentage of dry weight of the Salwey buds during the winter of 1926-27 (Table 21). There is an indication that when half of the branches of a tree were ringed, the buds borne on the girdled limbs had a slightly higher percentage of dry weight than those on the normal ones. These differences are too small in some instances to be mathematically significant. Fertilization with nitrate of soda may have increased the percentage of moisture in the buds as is indicated in the data, but the differences are too small in most instances to be significant. This probably was due to the early healing of the ringing wounds, so that the normal food movements were reestablished before cessation of growth.

TABLE 21.—*Influence of Ringing and Nitrogen Applications on Percentage of Dry Weight of Salwey Fruit Buds,* 1926-27

Row	Treatment		Percentage of Dry Weight on:		
			Nov. 15	Dec. 17	Jan. 28
30	Ringed	Limbs on the same trees	45.877	46.458	44.157
30	Not ringed		44.633	45.718	43.550
30	Ringed + nitrogen	Limbs on the same trees	47.496	47.075	45.704
30	Not ringed + nitrogen		46.423	45.437	43.651
31	Nitrogen		45.839	46.220	44.174
31	Check		46.332	46.577	45.199
29	Ringed + nitrogen		46.594	46.756	44.897
29	Ringed		46.306	46.865	45.372

Rather wide differences in the percentage of dry weight of the buds existed on January 17, 1928 (Table 22). The percentage of dry weight of the buds was significantly increased by the ringing in all cases. Applications of nitrate of soda had very little effect on the percentage of dry weight of the buds regardless of whether they had been ringed or not. The large difference in the percentage of dry weight of the buds of the Salwey and Greensboro should be pointed out, since the buds of the Greensboro contained from five to eight percent less water than the Salwey. Not all of this difference was in the floral parts of the buds, and the data would be misleading without an explanation.

Examination of the buds of the two varieties showed that those of the Greensboro differed in character from those of the Salwey. The scales of the former variety were not only larger, but there were more around each bud than in the case of the Salwey. Although the fruit buds of the Greensboro as they existed on the shoots were

larger in size and when removed weighed more than similar ones of the Salwey, yet when freed from scales they were considerably larger, as will be shown later. Since some of the scales were dead it is reasonable to assume that their water content was less than that of the floral organs. For this reason it would seem that the water content of the floral organs of the Greensboro buds was higher than the data indicate.

Bound Water of the Fruit Buds

The water held by the buds after drying for 144 hours at 30°C. has been termed bound water. Ringing by causing an accumulation of carbohydrates would, perhaps, increase the colloids of the cells which would be able to retain water against drying forces. To study this relation, determinations of the bound water in the buds were made during the winters of 1926-27 and 1927-28. These data are given in Tables 23 and 24. The treatments employed in these studies had very little effect on the percentage of bound water of the fruit buds, as the differences are small and not significant for either of the two years.

TABLE 22.—*Influence of Ringing and Nitrogen Applications on Percentage of Dry Weight of Greensboro and Salwey Fruit Buds on January* 17, 1928

Treatment		Percentage of Dry Weight of Buds	
		Salwey	Greensboro
Ringed	Limbs on the same trees	48.293±.144	56.887±.217
Not ringed		45.947±.176	52.814±.304
Ringed + nitrogen	Limbs on the same trees	48.695±.302	56.117±.377
Not ringed + nitrogen		46.066±.297	52.851±.155
Check		46.391±.202	53.790±.031
Nitrogen		45.911±.167	53.272±.059
Ringed		49.348±.290	57.033±.194
Ringed + nitrogen		49.675±.209	56.700±.105

There is an indication that ringing increased and that applications of nitrate of soda decreased the percentage of bound water of the buds. The differences between the various treatments although small are consistent and indicate that the conditions that caused accumulation of carbohydrates increased the percentage of bound water and hardiness of the buds. In both seasons the buds collected late in the winter had in most instances a smaller percentage of bound water than earlier. This was especially true during the winter of 1927-28. The decrease in bound water from early to late winter probably was due to the growth and other metabolic processes of the buds.

Size and Increase in Dry Weight of the Fruit Buds

As a measure of the growth of the buds during the winter months of 1926-27, the dry weight of 100 buds was calculated. Data are given in Table 25. These data show that the buds produced on ringed limbs or trees were larger on November 15, 1926, than those borne on similar ones not girdled. Fertilization had practically no influence on the size of the buds. During the winter months the buds of the fertilized trees made the most and the ones on the girdled limbs the

TABLE 23.—*Influence of Ringing and Nitrogen Applications on Percentage of Bound Water in Salwey Fruit Buds*, 1926-27

Row	Treatment	Sample Taken December 17, 1926			Sample Taken January 28, 1927		
		Percentage of Water Loss After 144 Hrs. at 30°C.	Percentage of Water Loss After 72 Hrs. at 73°C. in Vacuo	Percentage of Bound Water	Percentage of Water Loss After 144 Hrs. at 30°C.	Percentage of Water Loss After 72 Hrs. at 73°C. in Vacuo	Percentage of Bound Water
30	Ringed (Limbs on the same trees)	51.566	53.540	1.974	54.012	55.842	1.830
30	Not ringed (Limbs on the same trees)	52.367	54.281	1.914	54.629	56.449	1.820
30	Ringed + nitrogen (Limbs on the same trees)	50.869	52.924	2.055	52.549	54.294	1.745
30	Not ringed + nitrogen (Limbs on the same trees)	52.652	54.562	1.910	54.550	56.347	1.797
31	Nitrogen	51.806	53.777	1.971	54.132	55.825	1.693
31	Check	51.413	53.421	2.008	52.875	54.800	1.925
29	Ringed + nitrogen	51.286	53.242	1.956	53.354	55.102	1.748
29	Ringed	51.072	53.134	2.062	52.649	54.626	1.977

TABLE 25.—*Influence of Ringing and Nitrogen Applications on Dry Weight of 100 Buds. Salwey*, 1926-27

Row	Treatments	Average Total Dry Weight in Grams of 100 Fruit Buds on:				Percentage Increase in Total Dry Weight Nov. 15 to Jan. 28
		Nov. 15	Dec. 17	Jan. 28	Increase	
30	Ringed (Limbs on the same trees)	.584	.654	.704	.120	20.63
30	Not ringed (Limbs on the same trees)	.512	.604	.670	.158	30.98
30	Ringed + nitrogen (Limbs on the same trees)	.598	.684	.752	.154	25.83
30	Not ringed + nitrogen (Limbs on the same trees)	.554	.599	.730	.176	31.77
31	Nitrogen	.559	.692	.770	.211	38.01
31	Check	.554	.640	.700	.146	26.35
29	Ringed + nitrogen	.587	.679	.716	.129	22.01
29	Ringed	.608	.704	.736	.128	21.06

least increase in dry matter. It has been shown (Part I) that a high degree of negative correlation exists between the increase in dry weight of the buds during the winter and their susceptibility to winter injury. Data on the size and growth of the buds for the winter of 1927-28 will be considered later.

TABLE 24.—*Influence of Ringing and Nitrogen Applications on Percentage of Bound Water in Peach Buds,* 1927-28

Treatment		Percentage of Bound Water			
		Salwey		Greensboro	
		Jan. 17	Feb. 28	Jan. 17	Feb. 28
Ringed	Limbs on the same trees	1.974	....	2.309	....
Not ringed		1.771	....	2.121	....
Ringed + nitrogen	Limbs on the same trees	1.932	....	1.909	....
Not ringed + nitrogen		1.768	....	1.829	....
Check		1.771	1.580	2.011	1.658
Nitrogen		1.823	1.421	1.769	1.528
Ringed		2.067	1.552	1.948	1.684
Ringed + nitrogen		1.904	1.408	1.847	1.579

Percentage of Total Nitrogen in the Fruit Buds

The work of Curtis *(24)* and Harvey *(44)* showed that ringing reduces the percentage of nitrogen in the tissue above the ring. To study this relation in peach fruit buds the total nitrogen in samples of buds from the various treatments was determined three times during the winter of 1926-27, and twice in the winter of 1927-28. These data are given in Tables 26 and 27. Fruit buds produced on the trees that had received nitrate of soda contained a higher percentage of total nitrogen during the winter of 1926-27 than did those from similar ones not fertilized (Table 26). Ringing half of the main limbs of a tree reduced the percentage of total nitrogen in the buds above the rings. When all of the branches on a tree were ringed, fertilization increased the percentage of nitrogen in the buds.

TABLE 26.—*Influence of Ringing and Nitrogen Applications on Percentage of Total Nitrogen of Salwey Fruit Buds. Dry Weight Basis,* 1926-27

Row	Treatment		Percentage of Total Nitrogen in Fruit Buds on:		
			Nov. 15	Dec. 17	Jan. 28
30	Ringed	Limbs on the same trees	1.890±.063	1.930	1.983±.044
30	Not ringed		2.072±.039	2.002	2.097±.035
30	Ringed + nitrogen	Limbs on the same trees	1.926±.063	1.999	2.066±.082
30	Not ringed + nitrogen		2.193±.019	2.233	2.227±.061
31	Nitrogen		2.097+.049	2.121	2.136±.037
31	Check		1.872±.035	1.896	1.925±.024
29	Ringed + nitrogen		2.119±.067	2.164	2.237±.046
29	Ringed		1.899±.037	1.905	2.009±.027

In no case was there a reduction in the percentage of total nitrogen in the buds when all of the limbs were ringed as compared to those of the check trees. Apparently the ringing wounds had healed and sufficient time had elapsed for equilibrium between the nitrogen content of the root and top to have been reestablished. There is

some indication that the percentage of total nitrogen was slightly greater on January 28, 1927, than on November 15, 1926. Although the differences are small and not significant, they are all in that direction.

TABLE 27.—*Influence of Ringing and Nitrogen Applications on Total Nitrogen Content of Peach Fruit Buds,* 1927-28

Treatment		Percentage of Total Nitrogen, Dry Weight Basis			
		Salwey		Greensboro	
		Jan.17	Feb. 28	Jan. 17	Feb. 28
Ringed	Limbs on the same trees	1.617	....	1.291	....
Not Ringed		1.798	....	1.572	....
Ringed + nitrogen	Limbs on the same trees	1.658	....	1.328	....
Not ringed + nitrogen		2.079	....	1.722	....
Check		1.714	1.915	1.440	1.598
Nitrogen		1.942	2.081	1.609	1.703
Ringed		1.639	1.749	1.209	1.248
Ringed + nitrogen		1.874	1.936	1.236	1.301

The fruit buds borne on the main scaffold branches that had been ringed in late June, 1927, were found to contain significantly less total nitrogen during the winter of 1927-28 than the buds from similar normal limbs (Table 27). Ringing was more effective in reducing the nitrogen contained in the buds during the winter of 1927-28 than in the previous one. This probably was due to the difference in time of ringing. When all the branches were ringed and fertilized with nitrate the fruit buds contained significantly more total nitrogen than those of similar limbs that had been ringed but not fertilized. The data show that the Salwey buds contained a much higher percentage of total nitrogen than similar ones of the Greensboro. It should be pointed out that the water content of the buds was in the same relation as that of the total nitrogen during both winters.

TABLE 29.—*Influence of Ringing and Nitrogen Applications on Total Nitrogen in 1000 Fruit Buds, January* 17, 1928

Treatment		Average Total Nitrogen in 1000 Buds in Grams	
		Salwey	Greensboro
Ringed	Limbs on the same trees	.1219±.0043	.1166±.0021
Not ringed		.1424±.0053	.1317±.0022
Ringed + nitrogen	Limbs on the same trees	.1235±.0060	.1169±.0039
Not ringed + nitrogen		.1582±.0052	.1386±.0034
Check		.1415±.0014	.1284±.0021
Nitrogen		.1600±.0001	.1467±.0044
Ringed		.1246±.0078	.0987±.0010
Ringed + nitrogen		.1391±.0034	.1046±.0034

Total Nitrogen in One Thousand Fruit Buds

The total nitrogen contained in 1,000 fruit buds from the various treatments has been calculated for each of the two winters involved in the experiments. These data are given in Tables 28 and 29. Ringing had very little effect on the nitrogen content of the Salwey fruit

TABLE 28.—*Influence of Ringing and Nitrogen Applications on Total Nitrogen in 1000 Salwey Fruit Buds, 1926-27*

Row	Treatment		Average Total Nitrogen in 1000 Buds in Grams on: Nov. 15	Dec. 17	Jan. 28	Increase Nov. 15 to Jan. 28	Odds
30	Ringed	Limbs on the same trees	.1041±.0062	.1197	.1415±.0031	.0374±.0069	3902:1
30	Not ringed		.1069±.0089	.1212	.1410±.0069	.0341±.0113	23:1
30	Ringed + nitrogen	Limbs on the same trees	.1150±.0020	.1503	.1561±.0082	.0411±.0084	1029:1
30	Not ringed + nitrogen		.1215±.0038	.1339	.1623±.0058	.0408±.0069	14,969:1
31	Nitrogen		.1121±.0027	.1469	.1527±.0026	.0406±.0037	very high
31	Check		.1038±.0028	.1212	.1349±.0052	.0311±.0059	2644:1
29	Ringed + nitrogen		.1249±.0075	.1471	.1606±.0081	.0357±.0110	34:1
29	Ringed		.1157±.0022	.1342	.1479±.0010	.0322±.0024	very high

TABLE 30.—*Effect of Ringing and Nitrogen Applications on Percentages of Carbohydrates of Salwey Fruit Buds, 1926-27*

Row	Treatment	Percentage of Dry Weight of: Reducing Sugars as Glucose	Non-reducing Sugar as Glucose	Total Sugar as Glucose	Alcohol-soluble Non-sugars	Starch	Hemicellulose	Total Nitrogen	Moisture Percent
31	Check	5.55	2.48	8.03	7.69	4.54	11.38	1.925	54.80
31	Nitrogen	4.73	1.57	7.30	2.78	5.91	11.63	2.136	55.83
29	Ringed	4.29	1.92	6.21	10.35	8.00	10.00	2.009	54.63
29	Ringed + nitrogen	5.22	0.91	6.13	13.82	4.25	10.80	2.237	55.10

buds during the winter of 1926-27 (Table 28). The nitrogen content of the fruit buds was very largely determined by the amount of this material available to the trees, for in every instance buds produced on fertilized trees contained more total nitrogen than similar ones not fertilized. These differences are not great enough to be mathematically significant in some cases, but in view of the data it would seem that such a conclusion is justified. There was a significant increase in the nitrogen of the buds from November 15, 1926, to January 28, 1927. However, there was very little difference between the buds from the ringed limbs and the ones not girdled in this respect. The slight increase in the percentage of total nitrogen from November to the last of January would not account for the large gain found.

It has been shown that the fruit buds increased in dry weight from 20 to 38 percent. Thus, the larger amounts of total nitrogen in the buds in late January were largely due to their growth during this period. It should be mentioned not only that there was an increase in the amounts of nitrogen in the buds from November 15 to December 17, but also that they gained in dry weight. This is significant, since the trees are supposed to be in their deepest rest at this time of the winter. The increase in dry weight and total nitrogen of the buds from November 15 to December 17 was approximately the same as that for the slightly longer period from December 17 to January 28.

Samples were taken for moisture and nitrogen determination only on January 17, 1928, and for this reason the changes in the nitrogen content of the buds cannot be followed for the winter of 1927-28. Ringing decreased the amount of nitrogen of the buds regardless of whether all or only a part of the limbs were ringed (Table 29). The nitrogen content of the buds borne on ringed limbs was less than those of similar normal limbs or trees. Applications of nitrate of soda increased the total nitrogen content of the buds over that of similar trees not fertilized. Wide differences existed in the content of nitrogen in the buds of the Greensboro and Salwey. The Greensboro contained less moisture and nitrogen and, as will be shown later, made less growth during the winter months than the buds of the tender variety, Salwey.

Composition of the Fruit Buds

The preceding data have shown that the moisture, nitrogen, and growth relations of the fruit buds under certain conditions were materially altered by ringing and by the application of nitrate of soda. It has long been known that ringing interrupts the normal movement of carbohydrates (Curtis *(24)*, Harvey *(41)*, and others). In order to study the effects of ringing and nitrogen applications on the carbohydrate content of the buds, samples were taken for analysis from certain treatments on January 28, 1927. These data are given in Table 30. Ringing had considerable influence in altering the

carbohydrate composition of the Salwey fruit buds. This treatment reduced the percentage of total sugars present largely through its effect on the non-reducing sugars which occurred in smaller amounts.

The most striking result of the ringing was to increase greatly the percentage of alcohol-soluble non-sugars present. In this respect the composition of the buds of the ringed Salwey trees was similar to that of the hardy Greensboro (Table 16). The buds from the ringed trees were particularly high in starch, but when similar trees were fertilized the percentage of starch was greatly reduced. From this and other data already presented it is evident that the growth of the buds was determined, to some extent at least, by the amount of sugar present.

The variation in the carbohydrate composition of the buds was not as great as would be expected, considering the wide differences in growth and general behavior of the ringed trees as compared to similar ones not girdled. Each bud is composed of tissue of rapid growth and contains relatively little tissue that serves as storage organs. The growth and development of the bud is largely dependent upon the movement of food materials from the adjacent bark and wood as Curtis *(22, 23)* has shown for leaf buds. For these reasons, had analysis been made of the bark or wood adjacent to the buds, it is believed, greater differences in carbohydrates would have been found between the various treatments. The change in the general response of the trees after ringing indicates that this was true.

Growth and Development of the Buds During the Winter Months

It has been shown in the preceding pages that the fruit buds of the peach grow during the winter months and that the growth of the buds, as measured by their increase in dry matter and gain in total nitrogen, is influenced, in a measure, by the nutritional conditions of the trees during the season in which the buds are formed. To study this relation more carefully the increase in the diameter of the naked fruit buds and the development of the pollen, as influenced by the previous treatment, have been determined.

Increase in Diameter of the Naked Fruit Buds

In Table 31 are given the mean diameters and their probable errors of the naked fruit buds of the two varieties, Greensboro and Salwey, for the two periods during the winter of 1927-28. The probable errors are quite large, considering the nature of the material and the number of buds measured.

Buds produced on the basal portions of the shoots were as variable in size as those borne toward the terminals. The Salwey buds freed from scales were considerably larger than those of the Greensboro, and more variable in size. There is some indication that the buds borne on the terminal portions of the shoots were larger than those of the basal regions. However, the differences are not great enough to be significant. The basal buds were initiated first but in blooming they opened last. Thus it would seem that in early fall the

TABLE 31.—*Influence of Ringing and Nitrogen Applications on Increase in Diameter of Naked Fruit Buds of Peach from November 29, 1927, to February 6, 1928*

Variety	Row	Treatment	Position of Bud*	Nov. 29, 1927		Feb. 6, 1928		Increase in Diameter Nov. 29 to Feb. 6.
				No. of buds	Mean Diameter in Microns	No. of Buds	Mean Diameter in Microns	
Salwey	29	Ringed	T	26	1159±17	18	1424±24	265±29
	29	Ringed	B	16	1144±16	14	1463±27	319±31
	29	Ringed + nitrogen	T	22	1207±15	20	1490±16	283±22
	29	Ringed + nitrogen	B	21	1199±19	16	1467±25	268±31
	31	Check	T	22	1240±14	23	1579±18	339±23
	31	Check	B	14	1193±24	24	1532±22	339±33
	31	Nitrogen	T	26	1272±12	16	1557±19	285±24
	31	Nitrogen	B	13	1192±13	14	1531±22	339±26
Greensboro	27	Ringed	T	21	1087±11	20	1233±18	146±21
	27	Ringed	B	20	987±11	20	1157±14	170±18
	27	Ringed + nitrogen	T	20	1012±13	15	1176±12	164±18
	27	Ringed + nitrogen	B	27	954± 8	24	1132± 8	178±11
	31	Check	T	25	1027± 8	27	1260±11	233±14
	31	Check	B	23	1027±10	22	1248± 8	221±13
	31	Nitrogen	T	17	1090±10	20	1378±16	288±19
	31	Nitrogen	B	26	1032± 9	21	1320±14	288±17

*T—Buds from the terminal regions of the shoots. B—Buds from the basal region of the shoots.

basal buds were the largest and due to the more rapid growth of the terminal buds they later exceed the former in size and development.

Practically no difference in the diameter of the buds from the various treatments within a variety was evident on November 29. By February 6 the buds of all treatments had made a significant increase in diameter. The buds of the Salwey made a greater gain in diameter than those of the Greensboro. Certain treatments caused more rapid growth than others. Ringing significantly retarded the gain in diameter of the Greensboro buds regardless of whether nitrogen was applied or not. The effect of the ringing on the Salwey was not so marked, although the buds of the ringed trees made a smaller gain in diameter than those of the checks.

When nitrate of soda was applied to Greensboro trees similar to the checks, the buds produced on the fertilized trees made the greatest growth. Similar results do not follow for the Salwey, as the buds of the checks made as large a gain in diameter as they did on the trees which received nitrate of soda.

Development of the Pollen

Fruit buds on the same tree vary considerably in the stage of pollen development. There is a marked difference between the ones borne on the terminal and basal portions of the same shoots (Table 32). This is particularly true when the observations are made in late winter. It should be pointed out that even within the same bud there is considerable variation in the development of the pollen in the various anthers. For this reason the most advanced condition found in the bud has been taken as the stage of development for the particular bud.

Very marked differences were found between the two varieties in that the range of pollen development in the Salwey was much wider than in the Greensboro. The buds of the Salwey, although initiated later in the summer than those of the Greensboro, were the most advanced on November 29. The buds of the Salwey were mostly in the late archesporial stage while the ones of the Greensboro were largely in the early archesporial stage of development. The buds borne on the terminal portions of the shoots were more advanced than those of the basal regions. The buds from the terminal region of the shoots of the Salwey from the checks and from the trees that had been ringed and supplied with nitrogen were the most advanced on November 29. The buds from the trees that had only been ringed or fertilized were retarded in development.

From this time to February 6 there was a marked change in the pollen mother cells of the Salwey buds, no matter what treatment had been given the trees. By February 6 there were wide variations in the stage of pollen development of the buds of certain treatments. The pollen of the basal buds of the ringed trees ranged in development from pollen mother cell to that of the late tetrad stage, and the terminal buds of the check trees presented similar conditions. At this time the basal buds of the ringed Salwey trees were more

TABLE 32.—*Development of Pollen as Influenced by Ringing and Nitrogen Applications during the Winter of* 1927-28, *Expressed in Percentage of Total Buds of Each Group Examined*

Variety	Row	Treatment	Position of Buds*	November 29, 1927				February 6, 1928								
				Total Number of Buds	Early Archesporial Cells	Late Archesporial Cells	Early Pollen Mother Cells	Early Pollen Mother Cells	Pollen Mother Cells	Synapsis	Open Spireme	Diakenesis	Reduction Division	Early Tetrads	Late Tetrads	Total Number of Buds
Salwey	29	Ringed	T	26	15	85	..	..	5	67	17	..	11	..	..	18
	29	Ringed	B	16	19	81	..	..	7	43	22	..	7	14	7	14
	29	Ringed + nitrogen	T	22	..	59	41	..	5	55	35	5	6	..	..	20
	29	Ringed + nitrogen	B	21	..	100	..	..	19	38	31	6	..	..	..	16
	31	Check	T	22	..	50	50	..	9	26	53	4	..	4	4	23
	31	Check	B	14	7	93	..	..	25	50	21	4	..	..	..	24
	31	Nitrogen	T	26	..	100	..	..	..	12	38	25	19	6	..	16
	31	Nitrogen	B	13	23	77	..	..	..	29	64	7	..	..	..	14
Greensboro	27	Ringed	T	21	100	..	..	..	85	15	..	..	..	..	..	20
	27	Ringed	B	20	95	5	..	5	95	..	..	..	..	..	..	20
	27	Ringed + nitrogen	T	20	90	10	..	27	73	..	..	..	..	..	..	15
	27	Ringed + nitrogen	B	27	81	19	..	16	84	..	..	..	..	..	..	24
	31	Check	T	25	36	64	..	4	63	33	..	..	..	..	..	27
	31	Check	B	23	91	9	..	18	64	18	..	..	..	..	..	22
	31	Nitrogen	T	17	12	88	..	..	5	80	15	..	..	..	..	20
	31	Nitrogen	B	26	88	12	..	..	75	24	..	..	..	..	..	21

*T—Buds from the terminal region of the shoots. B—Buds from the basal regions of the shoots.

advanced than the ones borne on the terminal portions of the shoots. The terminal buds of the checks and the trees that received nitrogen were the most advanced. Although the data are not entirely clear it appears that the buds of the ringed trees, taken as a whole, as measured by pollen development were less advanced, and the ones receiving only nitrogen were, generally, more advanced than those of the check trees.

Taken as a whole, the buds of the fertilized Greensboro trees were more advanced on November 29 than those of the checks. The effect of ringing was to retard pollen development. By February 6 the pollen had developed materially and the growth of the buds had continued in about the same order as that found on the earlier date. That is, the buds of the fertilized trees were the most advanced, followed by the ones from the checks. When the trees were ringed and fertilized, the buds were less advanced than when they were only girdled. No explanation is available for this at present.

It would seem that, in general, fertilization with nitrate hastened and ringing retarded the development of pollen. The wide difference in the stages of pollen development between the two varieties should be pointed out. In every instance the pollen of the Salwey fruit buds was much more advanced than that of the Greensboro. This is very significant and lends emphasis to the view that the hardiness of the Greensboro is due, at least in part, to the slow growth of the buds during the winter months.

DISCUSSION

In these experiments ringing the main limbs of the trees about the middle of June did not have any material effect on the formation of fruit buds. The Salwey trees that received an application of nitrate of soda at bloom set a greater percentage of fruit buds in both years than similar trees not fertilized. In general, the fertilized Salwey trees formed as large a percentage of fruit buds as did those that were ringed and nitrated. It would appear then that ringing did not prevent the movement of nitrogen to the shoots, or that the trees were ringed too late to influence the formation of buds. It would seem that the latter view is the more probable.

These results lend emphasis to the view that fruit-bud formation is determined earlier in the growing season than has been evident from microscopical examination of the buds. The Salwey trees ringed on June 11, 1926, formed the same percentage of buds on the long shoots as on the short ones. The number of fruit buds on the normal trees decreased as the length of the shoots increased. It appears that ringing done at that time was sufficiently early to influence the formation of buds toward the apex of the long shoots but was without effect on the short ones.

Due to favorable weather conditions during both winters the injury to the fruit buds was not sufficiently severe to bring out the differences in the hardiness of the buds of the various treatments. The

data presented seem to show that the conditions that caused an accumulation of carbohydrates increased the hardiness of the buds. The hardiness of the buds of both varieties was significantly and negatively correlated with the length of the shoot on which the buds were produced. Then the nutritional conditions that cause some shoots to grow long and others short have an effect on the hardiness of the buds. It has been shown that the tender buds were high in moisture and nitrogen.

Ringing the trees in June materially reduced the percentage of water and nitrogen in the buds as well as the percentage of total sugars present, and increased the amounts of alcohol-soluble nonsugars. It would seem that the food reserves of the ringed trees were less readily available for growth than those of the checks. The buds on ringed limbs made less growth as measured by the increase in dry matter, less gain in diameter of the naked buds, and slower development of the pollen during the winter months than the ones produced on similar trees or limbs not ringed. This is in agreement with the results reported by Summers *(85)*, that the buds on ringed shoots of the cherry, apple, and pear are retarded in their development above the ring and accelerated for some distance below it.

PART III

The Influence of Partial Defoliation and Nitrogen Applications on the Formation, Growth, and Hardiness of Peach Buds

Under field conditions partial defoliation of peach trees occurs as the result of insect, disease, or spray injury. In some instances this partial defoliation has been considered to influence the susceptibility of the fruit buds to winter injury. On the other hand, Roberts *(76)* has reported that partial defoliation of cherry trees under certain conditions resulted in hardy buds. Conditions that prematurely remove the leaves usually reduce the amount of carbohydrates available to the trees. This may result not only through decreased photosynthesis but also from increased or prolonged growth of the trees, which may follow the defoliation, as has been shown by Harvey *(44)*. Prolonged or late growth involves the utilization of food materials and at the approach of winter less carbohydrates would be stored than in the case of trees making a normal growth. From this it could be deduced that tender buds would result from defoliation, since the tissues would be immature at the approach of winter, and the tissues probably would be relatively high in water and nitrogen and low in carbohydrates. In order to determine the effects of partial defoliation on the hardiness of peach fruit buds the following treatments were used.

Treatments

Experiments on partial defoliation were made only during one year. In order to insure the formation of fruit buds the trees were not defoliated until the very young buds were visible. Approximately

three-fourths of each leaf on one-half of each Salwey tree and on one of the four main scaffold limbs of each Greensboro tree were removed by cutting the leaf blade at right angles to the mid rib. The Greensboro trees were partially defoliated on July 21 and 22, and the Salwey on August 18 and 19, 1927. Following this partial defoliation the branches so treated started growth and put out new leaves at the terminals, which were removed from time to time. The previous treatments as well as the ones employed are given below.

Row 27. Salwey: 1925, Light dormant and two summer prunings. 1926, Corrective and two summer prunings. 1927, Corrective pruning and one-half of the main branches of each tree partially defoliated on August 17 and 18.

Row 28. Greensboro: 1925, Heavy dormant pruning. 1926, Corrective pruning. 1927, Corrective pruning and one main branch on each tree partially defoliated on July 21 and 22.

Row 31. Greensboro: 1925, Light dormant pruning. 1926 and 1927, no treatment. These trees were used as checks.
Salwey: Same as the Greensboro.

A standard 4-pound application of nitrate of soda was made at the time of blooming to every other tree in all rows.

EXPERIMENTAL RESULTS

The effects of the partial defoliation and nitrate applications on the growth of the trees and the formation and hardiness of the buds have been determined. Consideration has also been given to the effects of the treatments on the dry weight and total nitrogen content of the buds, as well as on the growth of the buds and pollen.

Growth and Blooming Response of the Trees Following Partial Defoliation

Soon after the branches were partially defoliated they started into growth and produced new leaves at the terminals, which were removed from time to time. The parts of the trees not defoliated were influenced by the partial defoliation of the limbs on the same tree to some extent, as the leaves became darker green in color and were retained later in the fall than leaves on similar trees not defoliated. Terminal growth on the partially defoliated branches continued late in the fall with the result that the shoots were very slender. The bark of these shoots was a brownish-green color entirely free of any bright pigments.

The following observations on leaf fall of the two varieties were made on November 7, 1927: Practically all the leaves of the Greensboro trees had fallen. What few leaves remained on the trees were on the branches that had been partially defoliated. The leaves on the partially defoliated branches of the Salwey trees were still dark green, and none or very few had fallen, while limbs on the same trees not defoliated retained about half their leaves which were still green.

The foliage of the untreated Salwey trees was yellow and about two-thirds or more had fallen, while similar trees that had been fertilized with nitrate of soda retained from one-half to two-thirds of the leaves. During the winter many of the tips of the shoots of the partially defoliated branches of the Salwey trees were killed, and usually about one-third of the shoot was injured, but on the defoliated and fertilized trees the injury was more severe.

From the data and from observations in the field it seems that the terminal portion of the shoots of the defoliated branches are more tender than the fruit buds. Because of this injury to the shoots the data to be presented later do not show the real differences that exist between the treatments, since in making the observations on injury only shoots that did not show injury were used.

The various treatments markedly influenced the time of blooming. As previously stated the Salwey trees left as controls bloomed about two days earlier than similar Greensboro trees. Blossoms appeared first on the branches of the partially defoliated trees. In this connection it is well to point out that some small branches below the rings on the ringed limbs bloomed at about the same time as the partially defoliated ones. The buds on the defoliated limbs opened from two to three days earlier than those on branches of the same trees which had not been defoliated. The latter bloomed slightly in advance of the trees that had been fertilized and these were closely followed by the checks.

These observations do not agree with those reported by Cooper and Wiggans *(18)*, since they found that the untreated trees came into bloom from one to three days earlier than the trees treated with nitrate. They also report that the buds of the untreated trees because of their advancement were more readily injured by the early spring freezes than the buds of treated trees. Chandler *(15)* also reports that late cultivation caused delayed blooming of peaches. The delayed flowering of the treated trees reported by Cooper and Wiggans and by Chandler may be due to a larger food storage than in the case of the untreated ones. The untreated trees may have had more wood and fruit to be supported per unit of leaf area, which resulted in storage of less food than in the case of the treated trees.

In view of the results reported in this paper it is to be expected that the buds on trees relatively low in soluble carbohydrates would make the least growth during the winter and bloom late in the spring. It would seem that this is the explanation rather than that fertilization or cultivation delays the inception and the breaking of the rest period. The treatments used in this study were designed to delay maturity and the entrance into the rest period. Nevertheless the buds from such trees made a greater growth and development during the winter than those of similar trees which are assumed to have entered the rest period earlier. It has been the writer's experience that such practices as summer pruning hasten the blooming of the trees in the following spring. This is probably due to a smaller carbohydrate storage than is the case in dormant pruned trees.

Formation and Hardiness of the Fruit Buds

In Table 33 are given the data for the formation and hardiness of the fruit buds as influenced by partial defoliation and nitrogen applications.

Fruit-Bud Formation

Partial defoliation had no effect on the percentage of fruit bud formation on the Salwey, but slightly decreased it on the Greensboro. Fruit bud initiation had probably proceeded farther at the time the Salwey trees were defoliated than with the Greensboro, since the trees of the latter variety were defoliated almost a month before those of the Salwey. Ringing the main branches on June 20 to 21 resulted in only a slight increase in fruit-bud formation in some cases, and it was suggested that this practice was done too late to influence the setting of buds except perhaps on the long shoots (Part II). The slight decrease in fruit-bud formation on the Greensboro following partial defoliation would seem to be a contradiction to the explanation offered for the effects of ringing. In the case of partial defoliation it is reasonable to assume that, even though fruit-bud formation had been initiated at the time of defoliation, the subsequent lack of carbohydrates limited the percentage of Greensboro buds that developed.

Hardiness of the Buds

It was unfortunate, as far as this study is concerned, that severe weather conditions were not experienced during the winter of 1927-28. The data of Table 33 show that partial defoliation had no effect on the percentage of the buds of either variety that came through the winter uninjured. The striking difference brought out by the data is the great amount of pistil killing of the buds of the Salwey that did not receive nitrate of soda. This injury was caused by low temperature in March following a warm period, as already pointed out. In every instance the pistils of the buds of nitrated trees suffered less injury than those not nitrated.

Limbs that had been partially defoliated had a lower percentage of buds with their pistils killed than similar ones not defoliated on the same trees. In this respect partial defoliation caused the buds to be more resistant to injury than the ones produced by a normal leaf area. When the percentage of the buds that were alive is added to the percentage of buds with the pistils killed the data show that defoliation caused the buds to be more tender than the ones borne on normal branches of the same trees.

The buds on the partially defoliated limbs were as hardy as those of the checks. Very little difference in hardiness or in the amount of pistil injury to the buds of the Greensboro was evident. There is some indication that the nitrate of soda applications or the partial defoliation by accelerating the development of the buds caused

TABLE 33.—*Influence of Partial Defoliation and Nitrogen Applications on Formation and Hardiness of Peach Buds,* 1927-28. *Greensboro Defoliated on July* 21 *and* 22. *Salwey Defoliated on August* 17 *and* 18

Variety	Row	Treatment	Total No. of Shoots	Average Shoot Length	Total No. of Nodes	Total No. of Buds Formed	Total No. Buds Alive After Last Freeze	Total No. Buds With Pistils Killed	Percentage of Buds Formed	Percentage of Buds Alive	Percentage of Buds With Pistils Killed	Percentage of Buds Alive and Percentage of Buds With Pistils Killed
Greensboro	31	Check	111	5.90	1287	1838	1488	13	71.41	80.96	.71	81.67
	31	Nitrogen	111	6.71	1331	1928	1553	59	72.43	80.55	3.06	83.61
	28	Not defoliated*	36	5.78	408	581	481	20	71.20	82.79	3.44	86.23
	28	Defoliated*	36	5.80	394	514	420	18	65.23	81.71	3.49	85.20
	28	Not defoliated + nitrogen*	36	6.64	431	606	506	26	70.30	83.50	4.29	87.79
	28	Defoliated + nitrogen*	72	6.68	906	1191	1017	40	65.73	85.39	3.36	88.75
Salwey	31	Check	108	6.19	1602	988	424	189	30.84	42.91	19.13	62.04
	31	Nitrogen	108	7.08	1673	1201	591	62	35.89	49.21	5.16	54.37
	27	Not defoliated*	72	6.17	976	588	213	256	30.12	36.22	43.54	79.76
	27	Defoliated*	72	8.28	1144	652	289	109	28.50	44.32	16.72	61.04
	27	Not defoliated + nitrogen*	72	6.78	1025	674	313	186	32.88	46.44	27.60	74.04
	27	Defoliated + nitrogen*	72	6.31	1004	673	351	49	33.51	52.15	7.28	59.43

*Limbs on the same trees.

the pistils of this variety to be more susceptible to freezing injury than those of the checks.

Dry Weight of the Fruit Buds

In Table 34 are given the data on the percentages of dry weight and the dry weights of 100 fruit buds from the various treatments. These data show that partial defoliation decreased the percentage of dry weight of the fruit buds of both varieties, but more significantly in the case of the Greensboro than with the Salwey. It has been shown that nitrate of soda applications decreased the percentage of dry weight of the buds. In this respect defoliation had a similar effect. The percentage of dry weight of the fruit buds of the defoliated branches or of those not defoliated on the same trees was not influenced by the treatment with nitrate. It has been shown in Parts I and II that hardiness of the buds was negatively correlated with their moisture content. It would seem then that in winters of low temperatures the buds of the partially defoliated trees would be more susceptible to winter injury than those produced on trees bearing a normal leaf area.

A striking effect of partial defoliation was to reduce the weight of the fruit buds (Table 34). In all cases the buds produced on the partially defoliated limbs were significantly smaller than those borne on limbs of the same trees which carried a normal leaf area. These data emphasize the fact that the fruit buds depend to a considerable degree upon the leaf area subtending them for their food supply.

Percentage of Total Nitrogen in the Fruit Buds

In view of the vegetative condition of the partially defoliated limbs it was suspected that the fruit buds contained a high percentage of total nitrogen. Harvey and Murneek *(45)*, working with defoliated apple spurs, found a narrow carbohydrates-nitrogen ratio which was due to an increase in the amount of nitrogen and reduction in the polysaccharides, although the amount of reducing sugars was increased to such an extent that the total carbohydrate content was but slightly altered by the defoliation.

When analyses were made of the fruit buds it was found that the buds borne on the partially defoliated limbs were lower in total nitrogen than those borne on the normal limbs of the same trees (Table 35). It should be pointed out that it is not entirely permissible to compare the results of the partially defoliated limbs or those of the same trees not defoliated with the checks, for the reason that the partially defoliated trees had been pruned each year before these studies were started. The data show, nevertheless, that partial defoliation reduced the percentage of total nitrogen in the buds as compared to that in the buds from limbs on the same trees not defoliated. This probably is due to the fact that the defoliated branches continued terminal growth too late in the fall. This would result in a utilization of the nitrogen in new leaf and shoot formation rather than in fruit-bud formation.

TABLE 34.—*Influence of Partial Defoliation and Nitrogen Applications on Percentage and Actual Dry Weight of Greensboro and Salwey Fruit Buds, January* 17, 1928

Treatment		Percentage Dry Weight		Dry Weight of 100 Fruit Buds in Grams	
		Salwey	Greensboro	Salwey	Greensboro
Not defoliated	Limbs on the same trees	45.701±.072	52.814±.304	.813±.005	.838±.011
Defoliated		45.492±.441	50.246±.341	.689±.011	.754±.018
Check		46.391±.202	53.790±.031	.843±.012	.892±.023
Nitrogen		45.911±.167	53.272±.059	.824±.009	.912±.012
Not defoliated + N	Limbs on the same trees	45.318±.312	52.851±.155	.781±.026	.805±.020
Defoliated + N		44.356±.243	50.934±.056	.699±.025	.699±.012

TABLE 35.—*Influence of Partial Defoliation and Nitrogen Applications on Percentage and Average of Total Nitrogen in* 1000 *Fruit Buds,* 1927-28

Treatment		Percentage of Total Nitrogen, Dry Weight Basis				Average Total Nitrogen in 1000 Buds in Grams on January 17, 1928	
		Salwey		Greensboro			
		Jan. 17	Feb. 28	Jan. 17	Feb. 28	Salwey	Greensboro
Not defoliated	Limbs on the same trees	2.016	....	1.572	....	.1535±.0061	.1317±.0022
Defoliated		1.681	1.924	1.549	1.628	.1158±.0007	.1206±.0018
Check		1.714	1.915	1.440	....	.1415±.0014	.1284±.0021
Nitrogen		1.942	2.081	1.609	....	.1600±.0001	.1467±.0044
Not defoliated + nitrogen	Limbs on the same trees	1.990	....	1.722	....	.1548±.0018	.1386±.0034
Defoliated + nitrogen		1.818	1.859	1.686	1.836	.1344±.0004	.1180±.0022

Total Nitrogen in One Thousand Fruit Buds

In order to show clearly the effects of partial defoliation on the total nitrogen content of the fruit buds, the amount of nitrogen contained in 1000 buds has been calculated and the data are given in Table 35. In every case the buds from the defoliated limbs contained significantly less total nitrogen on January 17 than the ones from the branches on the same trees which were not defoliated. The late growth of the partially defoliated branches had apparently used up the nitrogen, with the result that the buds were low in this material. The partial defoliation of a part of the branches on the trees influenced the amount of total nitrogen in the buds on the branches which had not been defoliated. In all cases the buds from the branches bearing a normal leaf area but from trees on which a part of the limbs were partially defoliated contained about the same amount of total nitrogen regardless of whether the trees had been fertilized or not. The amount of total nitrogen in the buds from these undefoliated branches was slightly less than in those from trees which received only nitrogen. These data show that defoliation of a part of the trees alters the nitrogen relations in the branches bearing a normal leaf area.

Growth and Development of the Fruit Buds

To determine the effects of partial defoliation and applications of nitrate of soda on the growth and development of the fruit buds during the winter months, samples of buds from the various treatments were collected for histological studies on November 29, 1927, and on February 6, 1928. To follow the changes that took place in the buds during this time two measures of growth have been used; the increase in the diameter of the naked fruit bud measured in that region where a straight line would bisect the ovules, and the development of pollen. These data are given in Tables 36 and 37.

Increase in Diameter of the Naked Buds

It has been shown that the buds produced on the partially defoliated branches weighed less than those borne on the same trees but on normal limbs. When the actual diameter of the naked buds is considered it was found that those borne on the partially defoliated shoots were as large on November 29 as those on the same trees produced by a normal leaf area (Table 36). By February 6 the buds of partially defoliated branches had increased in diameter until they were larger than the ones borne on the normal shoots. It is not possible to explain this difference in the size of the buds as measured by the two methods. The higher water content of the buds from the partially defoliated branches will not account entirely for this difference in size as determined by the two methods employed. The structure of the buds may have been changed by the partial defoliation, as observations in the field showed that these buds were the smallest, and in removing the scales from the buds there appeared to be fewer scales than when the buds were produced under normal conditions.

TABLE 36.—*Influence of Partial Defoliation and Nitrogen Applications on Increase in Diameter of Naked Buds from November 29, 1927, to February 6, 1928*

Variety	Treatment	Position of Buds†	November 29, 1927		February 6, 1928		Increase in Diameter Nov. 29-Feb. 6
			No. of Buds	Average Diameter in Microns	No. of Buds	Average Diameter in Microns	
Salwey	Not defoliated*	T	17	1201±10	16	1693±13	492±16
	Not defoliated*	B	25	1172±15	16	1590±21	418±26
	Defoliated*	T	20	1222±15	18	1706±36	484±39
	Defoliated*	B	23	1162±16	16	1609±27	447±31
	Check	T	22	1240±14	23	1579±18	339±23
	Check	B	14	1193±24	24	1532±22	339±33
	Nitrogen	T	26	1272±12	16	1557±19	285±24
	Nitrogen	B	13	1192±13	14	1531±22	339±26
	Not defoliated + nitrogen*..	T	25	1272±11	10	1662±35	390±37
	Not defoliated + nitrogen*..	B	24	1211± 9	16	1506±14	295±17
	Defoliated + nitrogen*	T	34	1268± 7	10	1704±25	436±26
	Defoliated + nitrogen*	B	16	1247± 9	13	1637±27	390±28
Greensboro	Not defoliated*	T	18	1076±10	19	1305±21	229±23
	Not defoliated*	B	13	992±10	15	1218±17	226±20
	Defoliated*	T	17	1011±14	18	1432±14	421±20
	Defoliated*	B	17	1008±12	18	1367±22	359±25
	Check	T	25	1027± 8	27	1260±11	233±14
	Check	B	23	1027±10	22	1248± 8	221±13
	Nitrogen	T	17	1090±10	20	1378±16	288±19
	Nitrogen	B	26	1032± 9	21	1320±14	288±17
	Not defoliated + nitrogen*..	T	16	1071±13	13	1251±17	180±21
	Not defoliated + nitrogen*..	B	16	986±13	14	1209±12	223±18
	Defoliated + nitrogen*	T	17	1064± 9	16	1308±21	244±23
	Defoliated + nitrogen*	B	20	1063±12	15	1267±15	204±19

*Limbs on the same trees.
†T—Buds from the terminal region of shoots. B—Buds from the basal region of shoots.

In no case was there any marked difference in the diameter of the buds from the various treatments on November 29. It seems that the buds borne on the terminal portions of the shoots were larger at this time than the basal buds. This is more clearly evident on February 6. In some instances the differences between the average diameters of the terminal and basal buds are too small to justify this statement, especially when the probable error is considered. The data would indicate that this was true, for in no instance was the mean diameter of the terminal buds smaller than that of the basal ones and in only three cases were they of approximately the same size.

There was a highly significant increase in the diameter of the naked buds of all treatments from November 29 to February 6. There were marked differences in the gains in diameter of the buds of Greensboro and Salwey. The Salwey buds made more growth than the Greensboro buds. This difference in the growth of the buds is very clearly one of the distinguishing varietal characteristics which accounts, in part, for the hardiness of the Greensboro.

Rather marked differences in the gain in diameter of the buds existed between the various treatments within the variety. The buds produced on the partially defoliated shoots of the Salwey made the greatest gain in diameter of all the treatments. When nitrogen was applied to similar trees there was some indication that the buds of both varieties made a smaller increase in diameter than when the trees were fertilized and the branches partially defoliated It has been shown that the buds from partially defoliated branches contained a smaller percentage and less total nitrogen than the ones from the same trees but from limbs bearing a normal leaf area.

There is a relation between the nitrogen content of the buds and their gain in diameter as has been shown to exist between nitrogen content and the increase in dry weight. It seems that in the case of the branches partially defoliated on trees treated with nitrate that the food materials have been used in wood or leaf growth at the expense of the buds, which results in a smaller gain in diameter of the buds during the winter months. There is very little difference between the increase in diameter of the buds borne on the terminal or basal portions of the shoots. The data of Table 36 do not show, perhaps, the true differences that exist between the various treatments for the reason that when the samples were taken on February 6 a considerable number of the buds produced on the terminal portions of the shoots were dead and had to be discarded.

Development of Pollen

Previous work has shown that the fruit buds of the peach are variable in size, in water, and in nitrogen content and that these characters are determined, in part, by the growth conditions of the trees during the season when the buds are formed. It has also been shown that the buds grow during the dormant season and that this growth of the buds as measured by the increase in dry matter and gain in total nitrogen is related to the nutritional conditions of the

TABLE 37.—*Development of Pollen as Influenced by Partial Defoliation and by Nitrogen Applications. Showing Range of Development Expressed in Percentage of Total Buds of Each Group Examined*

Variety	Treatment	Position of Buds on the Shoots†	November 29, 1927					February 6, 1928										
			Total No. of Buds	Early Archesporial Cells	Late Archesporial Cells	Early Pollen Mother Cells	Pollen Mother Cells	Total Number of Buds	Early Pollen Mother Cells	Pollen Mother Cells	Synapsis	Open Spireme	Diakenesis	Reduction Division	Early Tetrads	Late Tetrads	Microspores Liberated	One Nucleus Thin-Walled
Salwey	Not defoliated*	T	17	..	47	53	..	16	..	..	..	19	44	25	..	6	..	6
	Not defoliated*	B	25	..	100	..	..	16	..	..	6	38	56	..	..	..	..	..
	Defoliated*	T	20	..	10	90	..	18	..	5	6	11	22	17	17	6	17	..
	Defoliated*	B	23	..	100	..	..	16	..	..	12	38	50	..	..	..	..	..
	Check	T	22	..	50	50	..	23	..	9	26	53	4	..	4	4	..	..
	Check	B	14	7	93	..	..	24	..	25	50	21	4	..	..	..	..	..
	Nitrogen	T	26	..	100	..	..	16	..	..	12	38	25	19	6	..	..	..
	Nitrogen	B	13	23	77	..	..	14	..	..	29	64	7	..	..	..	..	..
	Not defoliated + nitrogen*	T	25	..	60	40	..	10	..	..	..	10	80	10	..	..	..	..
	Not defoliated + nitrogen*	B	24	4	96	..	..	16	..	6	19	50	25	..	..	..	..	..
	Defoliated + nitrogen*	T	34	..	32	53	15	10	..	..	..	40	10	20	10	10	10	..
	Defoliated + nitrogen*	B	16	..	81	19	..	13	..	..	..	54	31	15	..	..	..	..
Greensboro	Not defoliated*	T	18	..	89	11	..	19	..	37	48	5	5	5	..	..	..	..
	Not defoliated*	B	13	..	100	..	..	15	35	53	13	..	..	..	..	..	..	..
	Defoliated*	T	17	..	12	82	..	18	..	..	5	55	39	..	..	..	..	..
	Defoliated*	B	17	..	65	35	..	18	..	..	33	44	17	..	5	..	..	..
	Check	T	25	36	64	..	..	27	4	63	33	..	..	..	..	..	..	..
	Check	B	23	91	9	..	..	22	18	64	18	..	..	..	..	..	..	..
	Nitrogen	T	17	12	88	..	..	20	..	5	80	15	..	..	..	..	..	..
	Nitrogen	B	26	88	12	..	..	21	..	76	24	..	..	..	..	..	..	..
	Not defoliated + nitrogen*	T	16	..	56	44	..	13	..	38	54	8	..	..	..	..	..	..
	Not defoliated + nitrogen*	B	16	..	100	..	..	14	..	50	43	7	..	..	..	..	..	..
	Defoliated + nitrogen*	T	17	..	89	11	..	16	..	..	69	25	6	..	..	..	..	..
	Defoliated + nitrogen*	B	20	5	85	10	..	15	..	13	47	33	7	..	..	..	..	..

*Limbs on the same trees.
†T—Buds from the terminal region of the shoots. B—Buds from the basal regions of the shoots.

trees (Parts I and II). The effect of partial defoliation and nitrate applications upon the development of the pollen has been observed.

Realizing that only a relatively small number of buds could be examined by the tedious methods used, care was exercised in the collection of the samples so that they represented, as far as possible, the mean of the treatments. This was not possible with all of the samples taken on February 6, as there were many dead buds particularly on the shoots that had been partially defoliated. The largest number of dead buds were found on the terminal regions of the shoots, regardless of whether they had been fertilized or not.

Data for the development of the pollen in the buds from the various treatments are given in Table 37. These data show that the buds produced on the partially defoliated branches or on branches on the same trees not defoliated were the most advanced on November 29. The buds from the fertilized trees were slightly more advanced than those of the checks. In other words, the buds of the checks were the most retarded, and the pollen development of the buds of the other treatments followed rather closely the growth of the trees during the previous growing season. In general, the treatments that prolonged the growth of the trees hastened the development of pollen.

The buds borne near the terminals of the shoots were more advanced in pollen development than the basal ones. On November 29 the stage of pollen development of the two varieties was nearer the same than would be expected, considering the fact that the fruit buds of the Greensboro are initiated earlier than those of the Salwey. The Salwey buds on November 29 were slightly more advanced than those of the Greensboro. This shows that the buds of the Salwey develop much more rapidly than those of the Greensboro.

From November 29 to February 6 very significant changes took place in the pollen development in both varieties under all treatments. One of the most striking relations brought out by the data is the great difference in the development of the pollen of the Salwey as compared to that of the Greensboro. Although comparatively little difference between the two varieties was evident on the earlier date, by February 6 the buds of the Salwey were much farther advanced than those of the Greensboro. The rapid growth of the Salwey fruit buds explains, at least in part, the difference in the hardiness of the two varieties.

The data show marked differences between the various treatments within a variety in the development of the pollen. The buds from the partially defoliated trees were found to be more advanced than those from the checks. Partial defoliation of a part of a tree hastened the pollen development of the buds borne on the branches not defoliated but on the same trees. The buds produced on the defoliated branches were, however, more advanced than those from the same trees but borne on limbs that had not been defoliated.

It has already been pointed out that fertilization with nitrate of soda accelerated the development of the buds. When branches on trees treated with nitrate were partially defoliated the buds were not as far advanced as those on trees that had not received the nitrogen. It has been shown that defoliation and nitrogen applications reduced the gain in diameter of the buds from November to February as compared with those from similar partially defoliated trees which were not fertilized. The only explanation that can be offered for the slower pollen development of the buds borne on partially defoliated branches on trees that had been nitrated is that, probably, the food reserves were used up in the late growth of these trees and there was less food stored at leaf fall than in the case of similar ones not fertilized. The nitrogen content of the buds of defoliated and fertilized trees was less than that of the ones not fertilized and in view of the relationship that has been shown to exist between the nitrogen content and the increase in dry weight of the buds, the slow development of the former may have been due to the smaller amount of nitrogen present.

The buds borne on the terminal portions of the shoots were more advanced in pollen development than those of the basal regions. This agrees with the results reported by Knowlton and Dorsey *(56)*. Chandler *(16)* reports that the basal buds were more resistant to winter injury than those close to the terminals of the shoots. These relations indicate that the nutritional conditions existing in the various portions of the shoots influence the development of the pollen of the buds. The buds borne on the terminal portions of the shoots were generally more variable in development than those close to the base. It should be pointed out that the buds of the Salwey were more variable than those of the Greensboro. It appears that this variability in development is associated with susceptibility of the buds to winter injury.

DISCUSSION

Partial defoliation of certain branches, in July and August, after fruit bud formation had started resulted in renewed growth of the shoots of both varieties. These limbs retained their foliage late in the fall and the shoots were lacking in red pigments. The shoots were very slender and failed to increase in diameter, which is in accord with the results of Proebsting *(74)*, working with defoliated apple shoots. Considerable winter injury to the tips of the partially defoliated shoots occurred,—probably the result of immaturity caused by the late growth.

Partial defoliation slightly reduced the formation of fruit buds on the Greensboro but had little effect on the Salwey. Fruit bud initiation had probably proceeded to a greater extent in the Salwey, as the buds were allowed to develop far enough to be seen before the trees were defoliated.

The data presented show that partial defoliation had some effect on increasing the percentage of the buds that were injured by freezing temperatures. There were marked differences between the various treatments of the Salwey in the amount of winter injury to the pistils of the buds caused by a temperature of 23°F. in March, following a warm period. The buds of the trees that had been fertilized with nitrate were injured to a less extent than those not fertilized. It seems that the greater resistance of the pistils of the buds of the fertilized Salwey trees toward injury by freezing was due to the advanced stage of development of these buds at the time the low temperature occurred.

Partial defoliation materially reduced the percentage of dry weight of the buds. In view of this and the degree of correlation that has been shown to exist between the percentage of moisture of the buds and their hardiness it is believed that the buds of the defoliated branches were susceptible to injury at least in part because of their high water content.

The growth of the buds, as measured by their increase in diameter, was accelerated by partial defoliation. When the trees were fertilized and some of the branches partially defoliated, the buds produced did not gain in diameter as rapidly as those from the limbs that had only been defoliated. This was associated with the low nitrogen content of the buds and possibly with a low supply of food materials essential for growth. It is to be expected that when subjected to low temperatures the buds of partially defoliated and fertilized branches would be injured more than those not fertilized because of a greater degree of immaturity.

Partial defoliation not only accelerated the growth of the buds but it hastened the development of the pollen during the winter months. The fruit buds borne on the terminal portions of the shoots were more advanced than those produced toward the base. Knowlton and Dorsey *(56)* found the same relation to exist between the basal and terminal buds of other varieties. Abbott *(1)* cites some unpublished work of Hooker, who found that the basal buds contained less nitrogen and phosphorus but more water than the distal buds, and that the nitrogen and phosphorus increased from a low percentage in early fall to considerable amounts by the last of January.

Anderson and Hooker *(3)*, working with the cherry, showed that there was translocation of nitrogen from the other portions of the tree to the leaf and fruit buds. They found more nitrogen and water in the buds of the terminal region of the shoots than in those of the median or basal sections. Summers *(80)*, using apple shoots in which he injected various sugar solutions, found that the development of the buds was accelerated in all instances and that the ones nearest the points of injection made the earliest response.

GENERAL DISCUSSION

The data presented in the preceding pages on the influence of various practices on the formation, composition, and hardiness of the fruit buds of the peach show some irregularities which make the drawing of trustworthy conclusions difficult. During two of the three years in which these studies were made the winter conditions were so mild that there was comparatively little injury to the buds, and the data do not show, perhaps, the true difference in hardiness that existed between the various treatments. The data have, however, brought out some differences between the two varieties and between the various treatments within the variety which offer an explanation for some of the variations in hardiness of the fruit buds of the peach that are often observed in the field.

It has been shown that there is a wide difference between the Greensboro and Salwey varieties in the hardiness of the fruit buds, the former being much hardier than the latter. The hardiness of the buds is, in large part, determined by the moisture, nitrogen, and carbohydrate relationships which influence the growth of the buds during the dormant season. The buds of the Greensboro have been shown to be much lower in moisture, total nitrogen, and reducing and total sugars than the tender Salwey buds. Because of these relationships the buds of the former variety make less growth during the winter months than the Salwey.

It has been shown that the hardiness of the buds in both varieties is negatively correlated with the length of the shoot on which the buds are borne. The lack of hardiness is probably due to the more rapid growth during the winter of the buds on the long shoots as compared to those on the short ones. Knowlton and Dorsey *(56)* showed that the buds produced on long shoots are farther advanced during the winter than those borne on shoots less than six inches in length. The difference in the growth of the buds is determined, at least in part, by their water and nitrogen content, or by the nutritional conditions that made the long shoots grow long. On the same shoot the buds borne on the terminal portions are more tender than those of the basal regions. Data presented have shown that the buds borne near the terminals of the shoots are more advanced in development than are those near the base, which is in agreement with the results of Knowlton and Dorsey *(56)*. The more rapid the growth of the buds on the terminal portions of the shoots has been shown to be due probably to a higher moisture, nitrogen, and sugar content than that of the basal buds.

It was not possible, with the methods employed in this study, to increase the hardiness of the Salwey fruit buds so that it even approached that of the Greensboro, although the various practices used appreciably influenced the hardiness of the buds within the variety. Neither was it possible to change the moisture, nitrogen, and carbohydrate relationships of the buds of the Salwey so that they approximated those of the Greensboro. The treatments that caused the trees to be vegetative increased the percentage of water and nitrogen in the fruit buds. The treatments that reduced the vegetative conditions of the trees decreased the percentage of water and nitrogen present in the buds. It was not possible to build up a nitrogen or water content in the Greensboro buds to equal that of the Salwey.

It is believed that the greater growth response of the Salwey was due to the higher moisture, total nitrogen, and sugar content of the buds as compared with that of the Greensboro. The practices that increased these materials in the buds accelerated their development and reduced their hardiness. It was not possible to retard the growth of the Salwey buds so that they made the same growth response as the Greensboro which is probably due to the difference in the chemical composition of the two varieties.

From the data presented it appears that the conditions which accelerate the growth of the trees during the season when the fruit buds are formed likewise increase the growth and development of the buds during the dormant season. In no instance was there any evidence that would support the idea that late growth of the trees, within a variety, delayed the entrance of the buds into and their coming out of the rest period which was thought by Chandler *(15)* to be associated with the hardiness of the buds. From the data presented it seems that the rest period does not have a controlling influence on the growth of the buds but that they continue to grow and develop throughout the winter.

It has been shown by several investigators that the rest period of the peach is short and easily broken and often ends by the last of December or the first of January. Knowlton and Dorsey *(56)* found that the buds of the varieties Belle and Rochester made a slower growth response during the winter than did those of Elberta, which they thought was due to the shorter rest period of the latter variety. This, however, is a question of varietal difference and not one of influencing the rest period of the variety. It has been shown that low moisture, total nitrogen, and sugars are associated with retarded development of the buds, which may be due to a longer rest period or to the inhibition of growth caused by the accumulation of carbohydrates or other agents influencing protoplasmic activity.

Some evidence was found that the production of a crop of fruit caused the buds to be tender. This is in agreement with the results reported by Chandler *(16)*, who showed that removing the fruit by thinning increased the hardiness of the buds. The production of a crop of fruit apparently removes the carbohydrates and other food

materials in the fruit which are not replaced before leaf fall and result in buds susceptible to injury from cold. It appears that tender buds may result from a small leaf area per unit of tissue that must be supported during the winter. In other words, within a variety and for winter conditions even as mild as those of West Virginia the greatest degree of hardiness of the fruit buds of the peach is to be secured through the elaboration and storage of large amounts of food reserves.

The results of these studies suggest some procedures that should be followed in peach orchard management in order to secure the maximum resistance of the buds to winter injury. Since the greatest degree of hardiness was found in those cases where there was the greatest storage of food reserves it follows that a large and healthy leaf area should be maintained late into the fall. This can be accomplished by judicious cultivation, pruning, applications of nitrogen, and by the adequate control of insects and disease. Cultivation or the application of nitrogen carrying fertilizers should be made early in the spring to stimulate a quick growth of the trees and to produce a thrifty leaf area. The trees should be pruned in the dormant season and it should be of such severity as to regulate the bearing area without producing a vegetative condition of the trees. Over-bearing of the trees should be avoided by the proper thinning of the fruit.

SUMMARY

The investigations reported here are concerned with the influence of summer and dormant pruning, ringing, and partial defoliation with or without the application of nitrate of soda on the formation, composition, and growth of peach fruit buds in relation to their hardiness.

The two varieties Greensboro and Salwey were used for these studies as the former is hardy and the latter tender in the bud. The Greensboro forms a high and the Salwey a low percentage of fruit buds.

The practices used in these investigations had very little or no influence on fruit-bud formation on the Greensboro. Applications of nitrate of soda increased and summer pruning decreased fruit-bud formation on the Salwey. Ringing the branches about the middle of June or partial defoliation done in August had little effect on the formation of fruit buds on the Salwey. Fruit-bud formation had probably taken place before the trees were ringed or defoliated. Fruit-bud formation was found to be highly correlated with the length of the shoot on which the buds are borne. This correlation is positive with the Greensboro and negative with the Salwey.

There was a high degree of negative correlation between the hardiness of the fruit buds and the length of the shoots on which they were borne. The buds produced on the basal portions of the shoots

were hardier than those near the terminals. The practices that stimulated the growth of the trees caused the buds to be tender.

The results show that it was not possible by the treatments used to increase the hardiness of the Salwey fruit buds so that they were as hardy as those of the Greensboro.

Dormant or summer pruning decreased the hardiness of the fruit buds. Fertilization with nitrate of soda alone or in addition to pruning in most instances caused the buds to be susceptible to winter injury. The resistance of the buds to low temperatures was increased by ringing the branches about the middle of June. The results showed that partial defoliation reduced the hardiness of the buds.

During the winter about one-third of the tips of the shoots of the partially defoliated branches were winter killed. This injury was more severe on the trees that had also been fertilized with nitrate of soda. These results show that the shoots were, in this case, as tender or even more susceptible to injury than the fruit buds.

Evidence presented has shown that the killing of the pistils of peach buds by low temperatures in late winter may seriously curtail the prospects of a fruit crop. In some instances the pistils of the buds of ringed peach trees were less subject to injury than was the case when the branches were not girdled.

Partial defoliation or dormant or summer pruning with or without the application of nitrate of soda increased the water content of the buds. The effect of ringing the main branches was to reduce the percentage of water in the buds above the rings. The percentage of moisture in the buds was not constant but varied with the weather conditions during the winter. In warm weather the buds gained and in freezing weather they lost water. There was a high degree of negative correlation between the percentage of moisture in the buds and their hardiness.

The practices of partial defoliation, dormant or summer pruning, and nitrate of soda applications increased the percentage of total nitrogen contained in the buds. There was some indication that the percentage of nitrogen increased in the buds as the winter advanced, as it was slightly higher in late winter than earlier. Ringing the main branches was very effective in reducing the percentage of total nitrogen in the buds during one of the two years in which this was studied. A high degree of negative correlation existed between the total nitrogen content of the buds and their resistance to freezing injury. The water content of the buds was positively correlated with the percentage of nitrogen contained in them.

The buds increased in dry weight and total nitrogen during the winter months. The practices that stimulate the growth of the trees in the summer in which the buds are formed in most instances accelerated the gain in dry weight and total nitrogen of the buds during the winter. Coefficients of correlation have been calculated for one year between the percentage of buds alive and their total moisture and nitrogen contents. These coefficients were found to be $-.864 \pm .032$ and $-.679 \pm .068$, respectively.

Wide differences in the carbohydrate composition of the buds of the Greensboro and Salwey were found. The fruit buds of the Greensboro were low in reducing, non-reducing, and total sugars and starch but high in alcohol-soluble non-sugars and hemicellulose, while those of the Salwey were high in all sugars and starch but low in alcohol-soluble non-sugars and hemicellulose. Pruning or applications of nitrogen did not alter appreciably the carbohydrate composition of the buds. Ringing reduced the percentage of total sugars largely through the effect on the non-reducing sugar and increased the percentage of alcohol-soluble non-sugars and hemicellulose. The buds from the ringed branches of the Salwey approached the carbohydrate composition of the normal Greensboro trees. The evidence points to the conclusion that the food reserves of the Salwey fruit buds are in forms more readily available for growth and metabolic processes than those of the hardy Greensboro.

Histological studies showed that the fruit buds of both varieties developed during the winter months. The buds of the Salwey made the more rapid development, not only in the diameter of the naked buds but also in the differentiation of the pollen. The buds from the ringed trees made the least and those from the partially defoliated branches the greatest gain in diameter during this period. In general, ringing retarded and partial defoliation accelerated the development of pollen, with the buds of the check trees taking an intermediate position. Buds from the terminal portions of the shoots were generally more advanced than those from the basal regions of the same shoots as measured by pollen differentiation. There appears to be a high degree of positive correlation between the growth of the buds and their water, nitrogen, and soluble carbohydrate content. This is the explanation offered for the differences in the growth of the buds taken from variously treated trees or from different regions on the same shoot.

The data indicate that the effect of producing a crop of fruit is to reduce the hardiness of the buds. This is believed to be due to the removal of food materials in the fruit which are not replaced before leaf fall.

The greatest degree of hardiness of peach buds within a variety was found in those cases where there was the greatest storage of food.

BIBLIOGRAPHY

(1) ABBOTT, O.
1923. CHEMICAL CHANGES AT BEGINNING AND ENDING OF REST PERIOD IN APPLE AND PEACH. Bot. Gaz. 76: 167-184.

(2) AKERMAN, AKE, and JOHANNSON, H.
1917. BEITRAEGE ZUR KENNTNIS DER KAELTERESISTENZ DES WINTERWEIZENS. Ztschr. Pflanzenzucht. 5: 349-356.

(3) ANDERSON, A. G., and HOOKER, H. D.
1927. SOIL TREATMENTS AND SEASONAL CHEMICAL CHANGES IN THE SOUR CHERRY. Mo. Agr. Exp. Sta. Res. Bul. 108.

(4) APELT, A.
1909. NEUE UNTERSUCHUNGEN UEBER DEN KAELTETOD DER KARTOFFEL. Cohn's Beitr. Biol. Pflanz. 9:215-262.

(5) ASKENASY, E.
1877. UEBER DIE JAEHRLICHE PERIOD DER KNOSPEN. Bot. Zeitung 35:793-846.

(6) AUCHTER, E. C.
1923. IS THERE NORMALLY A CROSS TRANSFER OF FOODS, WATER AND MINERAL NUTRIENTS IN WOODY PLANTS? Md. Agr. Exp. Sta. Bull. 257.

(7) BEACH, S. A., and ALLEN, F. W.
1915. HARDINESS IN THE APPLE AS CORRELATED WITH STRUCTURE AND COMPOSITION. Iowa Agr. Exp. Sta. Res. Bul. 21.

(8) BLACKMAN, F. F.
1909. VEGETATION AND FROST. New Phytol. 8:354-363.

(9) BLAKE, M. A., and FARLEY, A. J.
1911. WINTER KILLING OF PEACH BUDS. N. J. Agr. Exp. Sta. Rept. 32:66-68.

(10) ———, and CONNORS, C. H.
1916. REPORT OF THE DEPARTMENT OF HORTICULTURE. N. J. Agr. Exp. Sta. Rept. 37:71-72.

(11) BRADFORD, F. C.
1922. OBSERVATIONS ON WINTER INJURY. 1. EARLY AND LATE WINTER INJURY. Mo. Agr. Exp. Sta. Res. Bul. 56.

(12) ———, and CARDINELL, H. A.
1926. EIGHTY WINTERS IN MICHIGAN ORCHARDS. Mich. Agr. Exp. Sta. Spec. Bul. 149.

(13) CARRICK, D. B.
1920. RESISTANCE OF THE ROOTS OF SOME FRUIT SPECIES TO LOW TEMPERATURES. Cornell Univ. Agr. Exp. Sta. Mem. 36.

(14) ———
1924. SOME EFFECTS OF FREEZING MATURE FRUITS OF THE APPLE. Cornell Univ. Agr. Exp. Sta. Mem. 81.

(15) CHANDLER, W. H.
1907. THE WINTER KILLING OF PEACH BUDS AS INFLUENCED BY PREVIOUS TREATMENT. Mo. Agr. Exp. Sta. Bul. 74.

(16) ———
1913. THE WINTER KILLING OF PLANT TISSUE BY LOW TEMPERATURE. Mo. Agr. Exp. Sta. Res. Bul. 8.

(17) ———
1925. FRUIT GROWING. New York.

(18) COOPER, J. R., and WIGGANS, C. B.
1926. A PRELIMINARY REPORT ON EXPERIMENTS WITH FERTILIZERS FOR PEACH TREES. Ark. Agr. Exp. Sta. Bul. 202.

(19) CRAIG, J.
1897. FRUIT BUDS OF PEACHES AND PLUMS—THEIR RELATIVE HARDINESS. Canada Exp. Farms Rept. 1896:153. 160.

(20) Crane, H. L.
1924. experiments in fertilizing peach trees. W. Va. Agr. Exp. Sta. Bul. 183.

(21) ———
1927. some results of top renewal of old peach trees. Proc. Amer. Soc. Hort. Sci. 24:248-252.

(22) Curtis, O. F.
1920. the upward translocation of food in woody plants. I. tissues concerned in translocation. Amer. Jour. Bot. 7:101-124.

(23) ———
1920. the upward translocation of food in woody plants. II. is there normally an upward transfer of storage food from the roots or trunk to the growing shoots? Amer. Jour. Bot. 7:286-295.

(24) ———
1923. the effect of ringing a stem on the upward transfer of nitrogen and ash constituents. Amer. Jour. Bot. 10:361-382.

(25) D'Arsonval, M.
1901. la pression osmotique et son role de defense contra le froid dans la cellule vivante. Comp. Rend. Acad. Sci. Paris 133:84-86.

(26) Davis, M. B.
1915. winter killing of cherry buds. report from the division of horticulture. Canada Dept. Agr. Rept. 1914:500-501.

(27) DeLong, W. A.
1928. pentosan content in relation to winter hardiness in the apple. Sci. Agr. 8:512-523.

(28) Dorsey, M. J., and Strausbaugh, P. D.
1923. plum investigations. I. winter injury to plum during dormancy. Bot. Gaz. 76:113-143.

(29) Doyle, Joseph, and Clinch, Phyllis.
1926. the pentosan theory of cold resistance applied to conifers. Sci. Proc. Roy. Dublin Soc. 18:219-235.

(30) ——— ———
1926. the dehydration rates of conifer leaves in relation to pentosan content. Sci. Proc. Roy. Dublin Soc. 18:265-275.

(31) Duhamel du Monceau, H. L., and Buffon, G. L. L.
1740. observations des differents effects que produisent sur les vegetaux les grandes gelees d'hiver et petites gelees du printemps. Mem. Math et Phys. Acad. Roy. Soc. Paris 1737:237-298.

(32) Dunn, Stuart, and Bakke, A. L.
1926. adsorption as a means of dltermining relative hardiness in apple. Plant Physiol. 1:165-178.

(33) Emerson, R. A.
1903. experiments in orchard culture. Neb. Agr. Exp. Sta. Bul. 79.

(34) ———
1906. the relation of early maturity to hardiness in trees. Neb. Agr. Exp. Sta. Ann. Rept. 19:101-110.

(35) Emery, S. M.
1899. sixth annual report. Montana Agr. Exp. Sta. Bul. 24.

(36) Gladwin, F. E.
1917. winter injury of grapes. New York Agr. Exp. Sta. Bul. 433.

(37) Goeppert, H. R.
1830. ueber die warmentwickelung in den pflanzen:deren gefrieren und die schutzmittel gegen dasselbe. Breslau.

(38) Gorke, H.
1907. UEBER CHEMISCHE VORGAENGE BEIM ERFRIEREN DER PFLANZEN. Landw. Versuch. Sta. 65:149-160.

(39) Green, W. J., and Ballou, F. H.
1904. WINTER KILLING OF PEACH TREES. Ohio Agr. Exp. Sta. Bul. 157.

(40) Greene, L.
1918. HORTICULTURE. Ind. Agr. Exp. Sta. Rept. 31:46.

(41) Haas, A. R. C., and Halma, F. F.
1928. PHYSICAL AND CHEMICAL CHARACTERISTICS OF EXPRESSED CITRUS LEAF SAP AND THEIR SIGNIFICANCE. Bot. Gaz. 85:457-461.

(42) Harris, J. A., and Poponoe, W.
1916. FREEZING POINT LOWERING OF THE LEAF SAP OF THE HORTICULTURAL TYPES OF PERSEA AMERICANA. Jour. Agr. Res. 7:261-268.

(43) Harvey, R. B.
1918. HARDENING PROCESSES IN PLANTS AND DEVELOPMENTS FROM FROST INJURY. Jour. Agr. Res. 15:83-112.

(44) Harvey, E. M.
1923. A STUDY OF THE GROWTH IN SUMMER SHOOTS OF THE APPLE WITH SPECIAL CONSIDERATION OF THE ROLE OF CARBOHYDRATES AND NITROGEN. Ore. Agr. Exp. Sta. Bul. 200.

(45) ———, and Murneek, A. E.
1921. THE RELATION OF CARBOHYDRATES AND NITROGEN TO THE BEHAVIOR OF APPLE SPURS. Ore. Agr. Exp. Sta. Bul. 176.

(46) Hildreth, A. C.
1926. DETERMINATION OF HARDINESS IN APPLE VARIETIES AND THE RELATION OF SOME FACTORS TO COLD RESISTANCE. Minn. Agr. Exp. Sta. Tech. Bul. 42.

(47) Hodson, F. R.
1923. OBSERVATIONS ON THE REST PERIOD OF DECIDUOUS FRUIT TREES IN A MILD CLIMATE. Proc. Amer. Soc. Hort. Sci. 20:151-155.

(48) Hooker, H. D.
1920. PENTOSAN CONTENT IN RELATION TO WINTER HARDINESS. Proc. Amer. Soc. Hort. Sci. 17:204:207.

(49) ———
1923. PEACH CULTURE IN MISSOURI. Mo. Agr. Exp. Sta. Bul. 207.

(50) Howard, W L.
1909. PROTECTING ORCHARDS AGAINST FROSTS AND FREEZES. Mo. Agr. Exp. Sta. Circ. 35.

(51) ———
1910. AN EXPERIMENTAL STUDY OF THE REST PERIOD IN PLANTS. Mo. Agr. Exp. Sta. Res. Bul. 1.

(52) ———
1915. AN EXPERIMENTAL STUDY OF THE REST PERIOD IN PLANTS. PHYSIOLOGICAL CHANGES ACCOMPANYING BREAKING OF THE REST PERIOD. Mo. Agr. Exp. Sta. Res. Bul. 21.

(53) Johnson, E. S.
1919. AN INDEX OF HARDINESS IN PEACH BUDS. Amer. Jour. Bot. 6:373-379.

(54) ———
1923. MOISTURE RELATIONS OF PEACH BUDS DURING THE WINTER AND SPRING. Md. Agr. Exp. Sta. Bul. 255.

(55) Knowlton, H. E.
1921. A PRELIMINARY REPORT ON HALF TREE FERTILIZATION. Proc. Amer. Soc. Hort. Sci. 18:148-149.

(56) ———, and Dorsey, M. J.
1927. A STUDY OF THE HARDINESS OF THE FRUIT BUDS OF THE PEACH. W. Va. Agr. Exp. Sta. Bul. 211.

(57) Lepeschkin, W.
1924. kolloidchemie des protoplasmas. Berlin.
(58) Lidforss, B.
1896. zur physiologie und biologie der wintergruenenflora. Bot. Centralbl. 68:33-44.
(59) Lott, R. V.
1926. correlation of chemical composition with hardiness in brambles. Mo. Agr. Exp. Sta. Res. Bul. 95.
(60) Macoun, W. T.
1907. report of the horticulturist. Canada Dept. Agr. Central Exp. Farms 1906:110-112.
(61) Martin, John H.
1927. comparative studies of winter hardiness in wheat. Jour. Agr. Res. 35:493-535.
(62) Maximow, N. A.
1912. chemische schutzmittel der pflanzen gegen erfrieren. Ber. d. deut. Bot. Gesell. 30:52-65.
(63) Molisch, H.
1897. untersuchungen ueber das erfrieren der pflanzen. Jena.
(64) ———
1907. ueber das gefrieren in kolloiden. Flora. 97:121-122.
(65) Mueller-Thurgau, H.
1880. ueber das gefrieren und erfrieren der pflanzen. Landw. Jahrb. 9:133-189.
(66) ———
1886. ueber das gefrieren und erfrieren der pflanzen. Landw. Jahrb. 15:453-610.
(67) Newton, Robert
1922. a comparative study of winter wheat varieties with especial reference to winter killing. Jour. Agr. Sci. 12:1-19.
(68) ———
1924. colloidal properties of winter wheat plants in relation to frost hardiness. Jour. Agr. Sci. 14:178-191.
(69) ———
1924. the nature and practical measurement of frost resistance in winter wheat. Univ. Alberta Col. Agr. Res. Bul. 1.
(70) Ohlweiler, W. W.
1912. the relation between the density of cell saps and the freezing point of leaves. Mo. Bot. Gard. Rept. 23:101-131.
(71) Pearson, Karl.
1914. tables for statisticians and biometricians. I-LXXXIII. 1-143.
(72) Pojarkova, Antonina.
1924. reservestoffe und kaelteresistenz bei holzpflanzen. Ber. d. deut. Bot. Gesell. 42:420-429.
(73) Potter, G. F.
1924. experiments on the resistance of apple roots to low temperatures. New Hamp. Agr. Exp. Sta. Tech. Bul. 27.
(74) Proebsting, E. L.
1925. the relation of stored food to cambial activity in the apple. Hilgardia 1:81-106.
(75) Rein, R.
1908. untersuchungen ueber den kaeltetod der pflanzen. Ztschr. fuer Naturwiss. 80:1-38.
(76) Roberts, R. H.
1917. winter injury to cherry blossom buds. Proc. Amer. Soc. Hort. Sci. 14:105-110.

(77) Rosa, J. T. Jr.
1921. INVESTIGATIONS ON THE HARDENING PROCESS IN VEGETABLE PLANTS. Mo. Agr. Exp. Sta. Res. Bul. 48.

(78) Sachs, J.
1860. UNTERSUCHUNGEN UEBER DAS ERFRIEREN DER PFLANZEN. Landw. Versuch. Sta. 2:167-201.

(79) Salmon, S. C., and Fleming, F. L.
1918. RELATION OF THE DENSITY OF THE CELL SAP TO WINTER HARDINESS IN SMALL GRAINS. Jour. Agr. Res. 13:497-506.

(80) Schaffnit, E.
1910. STUDIEN UEBER DEN EINFLUSS NEIDERER TEMPERATUREN AUF DIE PFLANZELICHE ZELLE. Mitt. Kaiser Wilhelms Inst. Landw. Bomberg 3:93-144.

(81) Schander, R., and Schaffnit, E.
1918. UNTERSUCHUNGEN UEBER DAS AUSWINTERN DES GETRIEBES. Landw. Jahrb. 52:1-66.

(82) Shutt, F. F.
1903. ON THE RELATION OF MOISTURE-CONTENT TO HARDINESS IN APPLE TWIGS. Proc. and Trans. Roy. Soc. Can. 9:149-153.

(83) Sinz, E.
1914. BEZIEHUNGEN ZWISCHEN TROCHENSUBSTANZ UND WINTERFESTIGKEIT BEI VERSCHIEDEN WINTERWEIZEN-VARIETAETEN. Journ. fuer Landw. 62:301-335.

(84) Strausbaugh, P. D.
1921. DORMANCY AND HARDINESS IN THE PLUM. Bot. Gaz. 71:337-357.

(85) Summers, F.
1923. FACTORS GOVERNING FRUIT BUD FORMATION. V. FURTHER EXPERIMENTS UPON THE RINGING AND NOTCHING OF FRUIT TREES. Jour. Bath and West. and South. Counties Soc. 17:140-144.

(86) ———
1923. FACTORS GOVERNING FRUIT BUD FORMATION. VI. THE STIMULATION OF BUD GROWTH IN CUTTINGS BY INORGANIC AND ORGANIC SOLUTIONS. Jour. Bath. and West. and South. Counties Soc. 17:145-149.

(87) Thayer, Paul.
1916. WINTER KILLING OF PEACH BUDS. Ohio Agr. Exp. Sta. Mon. Bul. 1:311-312.

(88) Webber, H. J., and others.
1919. A STUDY OF THE EFFECTS OF FREEZES ON CITRUS IN CALIFORNIA. Cal. Agr. Exp. Sta. Bul. 304.

(89) West, Frank L., and Edlefsen, N. E.
1921. FREEZING OF FRUIT BUDS. Jour. Agr. Res. 30:655-662.

(90) Whitten, J. C.
1899. THE RELATION OF COLOR TO THE GROWTH OF FRUIT BUDS OF THE PEACH ON SUNNY DAYS IN WINTER. Proc. Amer. Pom. Soc. 26:44-48.

(91) Wiegand, K. M.
1906. THE OCCURRENCE OF ICE IN PLANT TISSUE. Plant World 9:25-39.

(92) ———
1906. SOME STUDIES REGARDING THE BIOLOGY OF BUDS AND TWIGS IN WINTER. Bot. Gaz. 41:373-424.

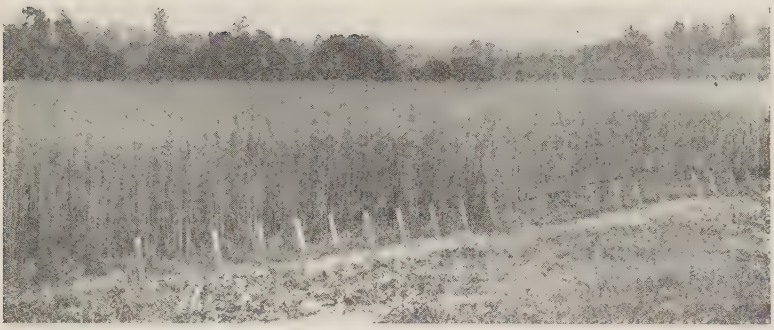
(93) Winkler, A.
1913. UEBER DEN EINFLUSS DER AUSSENBEDINGUNGEN AUF DIE KAELTERESISTENZ AUSDAUERNDER GEWAECHSE. Jahrb. Wiss. Bot. 52:467-506.

(94) Zacharowa, T. M.
1925. UEBER EINFLUSS NIEDRIGER TEMPERATUREN AUF DIE PFLANZEN. Jahrb. Wiss. Bot. 65:61-87.

Bulletin 237 October, 1930

Varietal Tests with Wheat, Oats, Barley, Rye, and Buckwheat

by M. M. HOOVER and R. J. GARBER



A Typical Small-grain Nursery on the Agronomy Farm

UNIVERSITY OF ILLINOIS LIBRARY

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

TABLE 1.—*Average yield and other characteristics of winter wheat grown (1921-1929) on the Agronomy farm at Morgantown*

Name of variety	W. Va. accession number	Variety from which selected	Average percentage of spring survival	Average date headed	Fruiting period in days	Average height in inches	Spike characteristics*	Average percent hardness	Yield in bu. per acre 1921-29	Yield in bu. per acre 1922-29	Rank in bu. per acre 1922-29
Fulhio	28	Fultz	72.3	6-2	36	41.0	A W S	60.7	27.5	28.5	1
Fulcaster	15	Fulcaster	65.7	6-4	37	44.1	B W S	46.9	25.8	26.4	2
Ashland	32	Fultz	65.1	6-2	36	41.0	A W S	59.9	24.2	24.8	5
Reliable 80	22	Gypsy	61.2	6-4	36	42.1	B W S	48.7	23.4	24.7	6
Check (Trumbull)	27	Fultz	63.9	6-2	36	41.5	A W S	68.9	23.2	24.0	7
Fultz 7	13	Fultz	68.4	6-3	36	40.3	A W S	64.4	22.9	22.9	8
Ohio 13384	26	Poole	62.2	6-2	38	41.3	A R S	50.4	22.7	23.6	9
Portage	30	Poole	60.6	6-2	39	39.4	A R S	50.9	21.8	23.0	10
Kentucky Selection	33	Currell's Prolific	58.3	6-2	39	40.2	A R S	61.3	21.3	21.7	12
Mammoth Red	43	Mammoth Red	60.3	6-4	38	43.3	B W S	67.6		25.1	3
Pennsylvania 44	46	Fulcaster	62.1	6-5	37	44.4	B W S	64.7		25.1	3
Currell's Prol.	40	Currell's Prolific	61.7	6-3	39	41.3	A R S	68.7		22.8	11
Bearded Purple Straw	42	Fulcaster	56.8	6-4	38	42.4	B W S	75.6		21.0	13
Leap's Prolific	41	Mediterranean Red	54.6	6-5	36	40.5	A W S	68.8		20.8	14

*A—awnless; B—bearded; W—white glumes; R—red glumes; S—glabrous glumes.

Harvesting the rod-row of wheat on the Agronomy farm

Varietal Tests with Wheat, Oats, Barley, Rye, and Buckwheat

by M. M. HOOVER and R. J. GARBER

THE PURPOSE of this bulletin is to present the results obtained to date from varietal experiments conducted by the West Virginia Agricultural Experiment Station with varieties of winter wheat and rye, as well as spring barley, oats, and buckwheat.

The individual grower cannot hope adequately to test each of the crop varieties which he grows. This is the function of the experiment station, since equipment, personnel, and funds are generally available for this purpose. It should be borne in mind that the relative value of varieties does not remain constant over a period of years but fluctuates in response to environmental changes. In order to reduce these fluctuations to a minimum, varietal tests should be carried on for a number of years and during this time all other factors should be held as nearly comparable as possible.

The experiments reported in this bulletin have been carried on for nine years. It is felt that data obtained during this time are sufficient to enable one to draw trustworthy conclusions and make recommendations as to the quality and yield of the varieties tested.

EXPERIMENTAL METHODS

The varieties were grown in plots consisting of three rows spaced one foot apart and 18 ft. long. Seeding was done by hand at the following rates per acre: wheat and rye, six pecks, barley, eight pecks, and oats, ten pecks. At harvest time one foot was cut from each end of the center row and discarded as border; the remainder of the row was cut, wrapped in muslin, and later threshed. In the case of oats the center row of the plot was shortened to 15 ft. The length of row of the harvested plot was varied in order to make it possible to use a convenient factor for calculating the yield of the different crops on an acre basis. Each variety was grown in four systematically replicated plots. Check plots were grown every third to fifth plot and were seeded to a recognized, good-yielding variety of the crop under test.

The Agronomy farm at Morgantown, where the varietal experiments have been carried on, has an elevation of about 1200 ft. The soil is classed as a Dekalb silt loam of medium fertility.

Field notes were taken on stands of the fall-seeded grains before the plots went into the winter. Comparison of this note with a similar stand note taken the following spring gave the data for winter killing. Prior to harvest, notes were taken on date of heading, height, and degree lodged, as well as head characteristics of the varieties tested.

A plot was considered headed when two-thirds of the plants were headed. The fruiting period as listed in Table 1 is the time in days between the date headed and the date ripe.

The percentage and degree of lodging note was taken to give an idea of the portion of the entire plot that was lodged as well as the degree of the lodging. Percentage of lodging, therefore, varies from 0 to 100, while the degree will vary from 0 to 90°. Thus a plot that was completely flat would be recorded as 90° lodged, whereas a plot which had one-third of its plants standing at an angle halfway between erect and horizontal would have recorded a note of 33%—45°.

Harvesting was done by cutting the center row of the plot with a sickle, and wrapping the bundle in muslin with the stake and tag which marked the variety in the field. The four bundles from the four plots of each variety were tied together, placed in a drying shed for several weeks, and then threshed.

Threshing of the varieties was done with a Minnesota type of rodrow thresher. In this type of machine only the heads of the grain are threshed. The thresher is so constructed that it can be quickly cleaned after the threshing of the four plots of a variety. The weight of threshed grain was recorded in grams, and by using a proper factor, this was converted to yield of bushels per acre.

Each sample of threshed wheat was inspected and a note taken on the percentage of hardness. This note was an estimate of the relative amount of corneousness of the threshed sample as compared with standards made up of definite numbers of hard and soft wheat.

Seed for the varieties was obtained from seed plots. These plots were usually grown in a separate part of the nursery and were carefully rogued and handled in such a manner as to reduce to a minimum the chance of mixture with other varieties. Yield data were not taken on these seed plots. Their only purpose was the production of pure seed from each variety represented in the variety test.

WHEAT VARIETIES

Soft Red Winter is the type of wheat generally grown in West Virginia. Statistics compiled by the United States Department of Agriculture show that the acreage of winter wheat has decreased in this state since about 1900; at that time 362,000 was the reported acreage for winter wheat. There was a very pronounced decrease in acreage between 1920 and 1928. The figures given are 219,000 acres in 1920 as compared to 122,000 acres in 1928. The average bushel yield per acre is given as 13. Although West Virginia produces only 0.3 percent of the wheat grown annually within the United States, the wheat crop within the state ranks next to corn in importance among the cereal crops produced.

In all, 18 named varieties of winter wheat were grown on the Agronomy farm. Nine of these varieties were grown for the full nine-year period. Six were grown for eight years, while V. P. I. No. 131, Forward, and Purkoff were grown for six, three, and two years, respectively.

The different named varieties are listed with the names under which they were introduced. These generally represent the better varieties from their respective states. Reliable 80, Fulcaster, and Fultz 7 were grown on the Agronomy farm before 1920. Fulhio, Ohio 13384, Trumbull, Portage, and Gladden were introduced from the Ohio Station; Ashland and Kentucky Selection from the Kentucky Station; Bearded Purple Straw, Currell's Prolific, Mammoth Red, and Leap's Prolific from the Maryland Station; Pennsylvania 44 from the Pennsylvania Station; V. P. I. No. 131 from the Virginia Station; Forward from Cornell University; and Purkoff from the Purdue Station.

In Table 1 are listed the average yield and other characteristics of 14 varieties of winter wheat grown at Morgantown during the years 1921 to 1929, inclusive. Nine of these varieties were grown for the entire nine years and can be considered as having grown under comparable conditions for this time. The highest-yielding variety, Fulhio, a pure-line selection of Fultz, made in 1912 at the Ohio Station, gave an average yield of 28.5 bushels. Fulcaster was second with an average yield of 26.4 bushels for this period. Kentucky Selection, a pure line from Currell's Prolific, made at the Kentucky Station, gave the lowest yield of the varieties that were grown for the entire period. It is of interest to note that the order of the varieties is but slightly changed when the five additional varieties which were grown in the varietal yield test for eight years are considered along with the nine varieties that were grown for the full period. The column in the table headed "Rank" (of varieties for yield per acre) gives the ranking of all varieties for the eight-year period.

When the average yields of the 14 varieties are studied critically it is found that a difference of 7.7 bushels is represented between the highest-yielding variety, Fulhio, and the lowest-yielding variety, Leap's Prolific. If these yield figures for the eight years are analyzed statistically it is found that this difference of 7.7 bushels is not as significant as one might expect. The reason for this is that the differences in yield between the varieties fluctuate considerably during the period of the experiment. In fact, the variety giving the lowest average yield during the 8-year period in one of the years actually produced a higher yield than the other one. This is of interest particularly when considered from the standpoint of the origin of the different varieties under test.

Four of these varieties—Fulhio, Ashland, Trumbull, and Fultz 7—represent pure-line selections from Fultz; Fulcaster, Penn. 44, Bearded Purple Straw, and Mammoth Red represent pure-line selections from Fulcaster or closely related types. Clark *et al* in their classification of American Wheat Varieties state that Mammoth Red is hardly distinguishable from Fulcaster, although from unpublished data Mammoth Red is classified as Silver Sheaf. The particular strain of Mammoth Red reported in this experiment was a pure-line selection of Mammoth Red made in 1912 at the Maryland Station. Ohio 13384 and Portage are both pure-line selections made from the Poole

variety at the Ohio Station. Kentucky Selection and Currell's Prolific are pure lines selected at the Kentucky Station and the Maryland Station, respectively, while Reliable 80 and Leap's Prolific represent selections of Gypsy and Mediterranean varieties, respectively.

In general those varieties having close genetic relationships show similar yields. For example, Ohio 13,384 and Portage, both selections from Poole, rank ninth and tenth with yields of 23.7 and 23.6 bushels, respectively. Fulcaster derivatives, consisting of Fulcaster, Penn. 44, Mammoth Red and Bearded Purple Straw rank second, third, fourth, and thirteenth with average yields of 26.4, 25.1, 25.1, and 21.0 respectively. Currell's Prolific and Kentucky Selection, both coming from Currell's Prolific variety, rank eleventh and twelfth with yields of 22.8 and 21.7. Reliable 80, a selection from Gypsy variety, ranked sixth with a yield of 24.7 bushels, while Leap's Prolific, the only selection from the Mediterranean variety, was lowest in yield with an average of 20.8 bushels for the eight-year period.

Gladden, a pure-line selection from Gypsy made at the Ohio Station in 1906, was grown for seven years during the experiment and gave an average yield of slightly less than Kentucky Selection.

V. P. I. No. 131, a pure-line selection made from Fulcaster at the Virginia Station, has been grown in the varietal experiment for six years and during this time has given an average yield of 23.5 bushels, while Fulcaster for the same period gave an average yield of 25.7 bushels. V. P. I. No. 131 closely resembles Bearded Purple Straw in performance, the records indicating that V. P. I. is headed two days ahead of Bearded Purple Straw but has a fruiting period only one day longer. Bearded Purple Straw has an average height of 8 inches more than V. P. I., whereas the spring survival and percentage of corneousness are almost indentical in the two varieties.

Forward, a variety produced by the plant breeding department at Cornell University, has been grown in the variety tests for three years. During this time it has proved to be one of the best-yielding varieties in the test, ranking second to Fulhio for the three-year period. Although three years is hardly sufficient time to test a variety, present indications show Forward to be a wheat well able to yield with the best sorts. This performance of Forward is particularly noteworthy since one of these winters, that of 1927, was very severe and many of the varieties winter killed to the extent of 75 to 80 percent or more.

Purkoff, a variety introduced from the Purdue Station, has been grown for two years. These years have not been marked by any adverse conditions; thus it is felt that the time is entirely too short either to commend or to condemn the variety. Yield and appearance thus far indicate that this variety is well adapted to conditions in West Virginia.

Percentage of spring survival is a measure of the ability of the varieties to withstand winter killing. The relative yielding ability of a variety over a period of years is no doubt determined very largely by its winter hardiness. As stated previously, the winter of 1927 was

particularly severe; many plots were entirely winter killed. Purkoff was by far the most hardy, showing a survival of 65 percent, whereas Fulhio, Fultz, Gladden, Ashland, and Fulcaster followed in the order named, with survivals of 46.5, 46.2, 30, 28.7, and 25 percent, respectively. When the average spring survival during normal years is close to 90 percent, it is seen that a winter like that of 1927 serves as a rigorous selective agency in determining hardiness.

The varieties tested did not show striking differences in regard to date of heading, fruiting period, and height. Although some differences were evident in regard to fruiting period, it was found that those varieties with relatively short fruiting periods were the best-yielding varieties. During the course of the experiment several varieties were dropped because of low yield. As a general rule, late maturity and low yield were found to be associated.

TABLE 2.—*Yield of winter wheat at Lakin,* 1923-1929

Variety	W. Va. accession number	Average yield in bushels per acre
Gladden	29	25.3
Reliable 80	22	23.9
Trumbull (check)	27	23.6
Fulhio	28	23.0
Mammoth Red	43	23.0
Currell's Prolific	40	22.7
Fulcaster	15	22.6
Fultz 7	13	22.5
Portage	30	22.3
Ashland	32	22.2
Penn. 44	46	22.0

Of the five high-yielding varieties for the eight-year period, three are awnless and two are awned. All five have white smooth glumes. Some wheat growers prefer awnless varieties because they are less disagreeable to handle than the awned varieties. So far as yield alone is concerned there seems to be no particular advantage of one form over the other.

Percentage of hardness or corneousness in bread wheats is usually associated with milling quality. Percentage of hardness in the varieties was found to fluctuate widely from year to year; however, within any year a variety would tend to be rather consistently high or low. Fulhio, the highest-yielding variety, shows an average percentage of hardness of 60.7, while Fulcaster, which was second in yield, shows a percentage of hardness of 46.9. Bearded Purple Straw has the highest percentage of hardness but the yield is next to the lowest. These figures show that there is a tendency to show a negative relation between yield and percentage of hardness. This relationship, however, is not sufficiently close to be considered causative.

From the data presented in Table 1 one may safely conclude that any one of the five or six best-yielding varieties over the eight-year period will give satisfactory performance under conditions similar to those existing at Morgantown. Personal preference should guide one in the further elimination of varieties and such characteristics as awned vs. awnless, height of plant, color, and texture of grain should be considered in making the final selection of a variety.

Wheat Experiments at Lakin

The variety experiments at Lakin were conducted at the substation in Mason County. This farm is located on second bottom and represents two soil types. Huntington is a silt loam of high productivity while Wheeling is fine sandy loam of relatively low productivity.

Table 2 contains data of wheat variety yields obtained at the Lakin substation for a period of six years. These varieties were grown in rod-row plots and were treated in a manner similar to the plots on the Agronomy farm at Morgantown. The center row of each plot was harvested and sent to Morgantown, where it was threshed and yields recorded. Since seed for the Lakin test and that of the Morgantown varieties came from the same source, any significant differences in yield may be attributed to soil and climatic factors.

Data are available for the years 1923-1929, with the exception of 1928, when the wheat varieties winterkilled to such an extent that it was felt the yield from the surviving plots would be of no value.

Gladden, Reliable 80, Trumbull, Fulhio, and Mammoth Red rank in the order named with yields of 25.3, 23.9, 23.6, and 23.0 bushels, respectively. A comparison of Tables 1 and 2 shows three varieties, Fulhio, Trumbull, and Reliable 80, to be within the five best varieties at Lakin as well as at Morgantown. Gladden, which gave the highest yield at Lakin, was one of the least desirable at Morgantown, with an average yield slightly less than Kentucky Selection. On the other hand, Fulcaster, which ranked second at Morgantown, was seventh in the yield trials at Lakin. These results indicate that no single variety was outstanding under conditions that vary as widely as those at Morgantown and Lakin, but it is shown that three of the five highest-yielding varieties gave satisfactory performance at both places.

OAT VARIETIES

According to the United States Department of Agriculture Year Book for 1928, the acreage of oats in West Virginia is something over 200,000. This represents approximately 0.4 percent of the oat acreage of the United States. In wheat there has been a marked decrease in acreage during the past decade, whereas in oats there has been a trend toward larger acreage. An average yield of 28 bushels is reported for 1928.

The yield of 23 varieties which were grown on the Agronomy farm at Morgantown are reported in Table 3. Albion, Gopher, Richland, and Common 60 Day were introduced from the Minnesota Station; Victory, Iowar, White Russian, Kherson, Fulghum, Swedish Select, and Early Mountain from the United States Department of Agriculture; Silvermine, Miami, Ohio 7009, Golden Rain, and Ohio 6222 from the Ohio Station; Japan Selection and New Zealand from the Pennsylvania Station; V. P. I. No. 1 from the Virginia Station; Markton from the Washington Station; Kanota from the Kansas Station; and Iogold from the Iowa Station.

On the basis of the nine-year average yield test, Albion leads with an average yield of 63.9 bushels. Iowar, Gopher, Japan Selection, and Silvermine rank in the order named with 60.9, 60.5, 60.4, and 59.5 bushels, respectively.

It is of interest to note that the relatively early, medium-tall varieties are those giving the most satisfactory performance over a period of years. Ability to resist lodging is desirable in oats. Data on percentage and degree of lodging are recorded in columns 5 and 6 of Table 3. Of the 18 varieties listed only two, Victory and Ohio 6222, show no lodging. Silvermine shows but slight lodging. Gopher has the least lodging of the early varieties with 1.4 percent and 2.8 degrees. This lodging of Gopher is significant due to the fact that Gopher was used as the check variety and occurred every fifth plot throughout the nursery. It thus had ample opportunity to occupy unfavorable plots more frequently than the other sorts that were grown in only four systematically distributed plots each year.

TABLE 3.—*Average yield and other characteristics of oat varieties grown on the Agronomy farm at Morgantown* (1921-1929)

Name of variety	W. Va. accession number	Average date headed	Fruiting period	Height	Lodging		Average yield (1921-1929)
					Percent	Degree	
Albion (Iowa 103)	27	6-17	30	33.3	13.2	17.5	63.9
Iowar C. I. 847	15	6-22	27	33.9	6.6	16.0	60.9
Check (Gopher)	25	6-20	29	32.7	1.4	2.8	60.5
Japan Select.	21	6-25	26	40.2	1.1	12.0	60.4
Silvermine	4	6-24	28	36.3	0.2	1.0	59.5
Early Mountain	11	6-28	26	39.8	6.9	13.4	58.5
Iowa 105 (Richland)	26	6-17	31	30.7	6.2	10.5	58.0
Com. 60 Day	24	6-17	30	32.9	13.2	17.7	57.7
New Zealand	19	6-29	27	39.1	2.7	3.5	57.6
Ohio 6203 (Miami)	1	6-26	29	37.6	0.4	6.0	57.5
Victory C. I. 560	8	6-29	27	39.2	0.0	0.0	57.3
Fulghum	12	6-18	32	33.4	8.1	11.6	57.1
Ohio 7009	3	6-15	29	31.8	3.0	18.0	56.9
Swedish Select. C. I. 134	9	6-27	28	38.6	2.9	4.9	56.8
Kherson C. I. 459	16	6-17	30	31.7	9.0	20.8	56.3
Golden Rain	5	6-28	27	39.8	2.8	5.1	55.8
Ohio 6222	2	6-29	26	36.7	0.0	0.0	55.6
White Russian	10	7-2	27	41.2	0.8	10.0	48.2

Albion, although ranking highest in yield, showed lodging in five out of nine years. During certain of these years Albion was the most severely lodged variety in the nursery. This tendency to lodge makes it of doubtful value for general culture. Gopher during this same period of years showed but 1.4 percent and 2.8 degrees on all of the plots on which it was grown. No lodging whatever was recorded for Gopher in seven out of nine years. The heavy lodging of 1928 is largely the result of a severe wind storm just preceding harvest.

Iowar C. I. 847, like Albion, showed severe lodging in four of the nine years. Thus, of the five highest-yielding varieties, the first two should be discriminated against on the basis of their weak straw. Japan Selection and Silvermine show a fairly desirable record as to lodging, but because of their mid-season maturity they often are adversely affected by weather conditions at the time of ripening.

White Russian was the only variety included in the test that was

of the side or horse-mane type. The low average yield of this variety indicates that it is not adapted to the conditions under which this experiment was carried out.

Gopher is easily the first choice since it combines the desirable qualities of satisfactory yield with earliness and stiff straw.

Oat Variety Experiments at Lakin

Seven varieties were grown in the oat variety test at Lakin. The seed for these varieties was produced at Morgantown with the exception of the check, which was a variety of good yield grown in the vicinity of the substation.

Albion was high with a yield of 54.5 bushels. The local variety ranked second and Gopher third with average yields of 52.6 and 52.4 bushels per acre, respectively. Richland, Fulghum, New Zealand, and Victory averaged 51.8, 49.7, 47.5, and 46.2 bushels per acre, respectively.

It is significant to note that the high-yielding varieties at Lakin as well as at Morgantown were early-maturing varieties. The fact that Albion has undesirable straw should be considered when a choice of variety is made for general culture.

Table 4.—*Average yield and other characteristics of winter rye grown* (1922-1929) *on the Agronomy farm at Morgantown and at Lakin*

Name of variety	West Va. accession number	Average date heading	Fruiting period	Average height in inches	Morgantown av. yield in bu. per A.	Lakin av. yield in bu. per A.
Rosen	1	5-19.5	50	52.6	31.1	38.6
Abruzzes C. I. 40	2	5-15.6	56	54.6	29.2	36.6
Minnesota 2	13	5-17.1	54	54.8	28.8	38.3

RYE VARIETIES

The acreage of winter rye in West Virginia never has been very great. The agricultural census for 1920 gives an acreage of 9000 with an average yield of 13 bushels. Hampshire, Morgan, Pendleton, Hardy, and Berkeley Counties produce most of the rye that is grown for grain in this state. This comparatively low acreage of rye is not surprising since the chief use of rye is as a cover crop.

Three varieties of winter rye were included in the tests made at Morgantown. These were grown in the fall-seeded nursery and were handled in every respect like the wheat varieties.

Table 4 gives the average yield and other characteristics of winter rye grown at Morgantown and at Lakin. Rosen has given the best yield for the six-year period during which this experiment has been conducted. Abruzzes C. I. 40 and Minnesota No. 2 ranked second and third in yield. The same three rye varieties were grown at the Lakin substation and here Rosen again gave the best yield, while Minnesota No. 2 was second and Abruzzes C. I. 40 was third. There was no great difference in yield between the varieties as shown in the accompanying table. Quality of grain as measured by size, color, and plumpness was decidedly in favor of Rosen in both tests.

BARLEY VARIETIES

Table 5 gives the average yield and other characteristics of spring barley grown on the Agronomy farm at Morgantown for the years 1922-1929, inclusive. All varieties are bearded, six-rowed types with covered seeds, with the exception of Chevalier, a two-rowed type. Wisconsin Pedigree was obtained from the Wisconsin Station; all other varieties, from the U. S. Department of Agriculture.

It will be noted from Table 5 that Alpha has the highest average yield for the duration of the experiment. This variety is of hybrid origin and is the result of a cross of Manchuria x Champion of Vermont, the latter being the pollen parent. Wisconsin Pedigree has been grown for five years. The last column gives the average yield of all varieties for this five-year period. The order of yield is not changed from that of the eight-year period except for the Wisconsin Pedigree and Chevalier varieties. Chevalier is a two-row sort and is distinctly lower in yield than any of the other varieties. The poor yield is due in part to the late maturity of this variety.

TABLE 5.—*Spring barley varieties on the Agronomy farm,* 1922-1929

Variety name	West Va. accession number	Date headed	Fruiting period	Average height	Yield in bu. per A. 1922-29	Yield in bu. per A. 1925-29
Alpha C. I. 959	7	6-19	31	32.1	35.5	38.0
Manchuria C. I. 643	6	6-18	31	28.9	31.3	34.0
Oderbrucker C. I. 1174	9	6-18	30	28.7	30.4	32.6
Featherstone C. I. 1120	8	6-17	31	30.1	29.2	32.1
Chevalier C. I. 278	4	6-23	29.4	27.0	26.1	22.6
Wisconsin Pedigree C. I. 835	10	6-20	31	30.1		31.5

Barley has never been an important grain crop in West Virginia. This is due largely to the fact that barley must compete with oats if seeded in the spring. Yields of barley do not compare favorably with our better oat varieties. Winter barleys have been grown at both Morgantown and Lakin but yields are very low. This is attributed to winter killing in most cases. Growers and feeders of barley would prefer awnless or smooth-awned types. Yield tests conducted thus far have shown bearded sorts to give much better results than any awnless varieties known at the present time.

BUCKWHEAT VARIETIES

According to the statistics compiled in the 1928 Year Book of the United States Department of Agriculture, West Virginia has an annual acreage of 40,000 acres which are devoted to the raising of buckwheat. This acreage has remained fairly constant during the last ten years. Preston County with 10,000 acres ranks first in acreage and production. Hampshire, Barbour, Morgan, and Tucker rank in the order given. The average yield for the state for the past twenty years is approximately 20.0 bushels as compared to an average for the United States during this same period of 18.5 bushels.

Table 6 gives the name, West Virginia accession number, and yield of eight strains of buckwheat that were included in the variety tests during the years 1921-1927, inclusive. Two types of buckwheat are represented. C. I. 91 Mountain belongs to the Fagopyrum

TABLE 6.—*Buckwheat varieties on the Agronomy farm, Morgantown*

Name	West Virginia accession no.	Average yield 1921-27
U. S. Japanese Sel.	7	23.8
Check Japanese	8	23.3
Scarlett's Japanese	1	22.3
Wood's Japanese	3	21.9
U. S. Japanese	2	20.4
Wood's Silverhull	5	19.8
C. I. 91	6	19.4
U. S. Silverhull	4	17.4

tataricum while the seven remaining varieties belong to Fagopyrum esculentum species. West Virginia accession numbers 4 and 5 represent strains of Silverhull, while accession numbers 1-2-3-7-8 are strains of Japanese.

Silverhull and Japanese varieties are the two most widely grown in West Virginia. As a result of these variety tests, the Japanese strains are shown to be superior to the Silverhull. Millers seem to favor the Silverhull variety because the flour is better in color and, it is claimed, gives a higher milling percentage. Japanese is objected to because the dark, coarse hulls give a flour of inferior grade. Since differences in yield are very much in favor of Japanese it is felt that the increase in yield is sufficient to more than offset the difference in milling quality. Mountain buckwheat matures between ten days and two weeks later than the esculentum types. This difference in maturity is thought to be one of the chief causes for its poor yield.

SUMMARY

Varietal experiments were carried on with wheat, oats, rye, barley, and buckwheat at Morgantown for nine years; and with wheat, oats, and rye at Lakin for seven years.

Fulhio, Reliable 80, and Trumbull were among the five highest-yielding varieties of winter wheat both at Morgantown and Lakin. These three varieties have given consistent results and can be relied upon to give a satisfactory performance under average West Virginia farm conditions. Fulhio and Trumbull are awnless varieties while Reliable 80 is a bearded variety.

Albion, Iowar, and Gopher have given the most satisfactory yields among the varieties of oats that were tested. Gopher is the most satisfactory variety since it combines the good qualities of earliness, yield, and stiffness of straw. Albion is of questionable value for general culture because it has a weak straw that permits lodging during most seasons.

Three varieties of winter rye were grown both at Morgantown and Lakin. Rosen gave the highest average yield but differences between the varieties tested were not great.

Alpha barley gave an average yield of four bushels more than any other spring barley tested. This barley is of hybrid origin and seems to show considerable promise for those sections of the state where barley is grown in preference to oats. Winter barleys were grown both at Morgantown and Lakin but were found to give unsatisfactory yields at both places.

Japanese buckwheat produced an average yield of four bushels more than Silverhull for the period of the test.

Bulletin 238

ARIZ. UNIV. LIB. JAN 23 1931

November, 1930

The West Virginia Community Packing House at Inwood as a State Service to Apple Growing

by F. J. SCHNEIDERHAN

The Barrel Label for the U. S. No. 1 and Fancy Grades

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

Typical terrain of orchard country
in the Eastern Panhandle

*The West Virginia Community Packing House at Inwood as a State Service to Apple Growing**

by F. J. SCHNEIDERHAN

THE West Virginia Community Packing House at Inwood has been in existence since 1920. During the 9-year period of its activities it has rendered important service to apple growing throughout the state and particularly in the Eastern Panhandle, where it is situated. The purpose of this bulletin is to present a report of a community cooperative packing plant originally and subsequently aided by state funds but actually functioning as a cooperative venture between the state and a group of apple growers designated as the Inwood Fruit Growers.

The history of the apple industry in the Eastern Panhandle is one of a multitude of production and marketing problems. As in other apple-growing sections, the chief problems in the early stages of the industry were those of production. Hundreds of varieties, including seedlings, were planted without regard to adaptation to the section. Little was known about the selection of orchard sites, planting distances, pruning, or fertilizing. Spraying was unknown. Whitewashing of treetrunks was considered the panacea for all the ills of apple trees. Artificial cold storage was unknown.

With the development of extensive apple-tree plantings came problems of pest control, the major ones being San Jose scale, codling moth, scab, and cedar rust. Investigations of the control of these pests were undertaken by the State Agricultural Experiment Station and the knowledge obtained was disseminated to the farmers.

The encroachment upon the market of carefully graded apples from the Pacific Northwest brought further hardship upon the eastern grower. The packing of inferior fruit brought the barrel pack into disrepute and opened the way for the introduction of the high-class boxed apples from the West. When a number of Panhandle orchardists undertook to pack a high grade of apples, they found their fruit in competition with poorer packs from the same district, and the price level was determined by such inferior grades.

*Submitted for publication March, 1929.

Acknowledgment

The author acknowledges the assistance rendered by H. W. Prettyman, superintendent, and H. W. Hammersla, bookkeeper of the Inwood Packing House; J. J. Gardner and B. C. Boree of the U. S. Bureau of Agricultural Economics; and J. H. Brunk, superintendent of the C. H. Musselman Company by-products plant.

The first efforts to meet this situation were directed toward selling the fruit rather than standardizing the grading and packing, but the history of these efforts is a series of failures. Among the few successful undertakings was the Martinsburg Fruit Exchange, strictly a sales agency organized along cooperative lines. This association became the logical group to lead the attempt to standardize the apple pack in the Panhandle.

FIG. 1.—The West Virginia Community Packing House building, erected in 1920. The capacity of the packing house is approximately 40,000 barrels of apples per season. A total of 25,702,664 pounds of apples was handled in this building up to and including 1927

After a few years it was realized that the problem was larger than any single well-organized body could hope to counter successfully. The State Legislature was asked to assist. In 1919 an act was passed providing for the establishment of a demonstration packing plant. Objectives as stated in the act follow:

"*Demonstration Community Packing House.*—There is hereby established a demonstration community packing house to be located in the principal apple-growing section of the state, for the purpose of demonstrating the most approved methods of picking, sorting, and packing apples, peaches, and similar fruit, and for the purpose of teaching any citizen of West Virginia approved methods of picking, sorting and packing said fruit in barrels, boxes, or other containers, and for the purpose of carrying the provisions and purposes of this act into effect a committee is hereby created consisting of the dean of the College of Agriculture of West Virginia University, the commissioner of agriculture, the president of the state Horticultural Society, the chairman of the horticultural committee of the state Farm Bureau Federation, and the horticulturist of the West Virginia Agricultural Experiment Station. It shall be the duty of the State Board of Control to procure a site, erect buildings and pre-cooling room, and provide the equipment and necessary space for the aforesaid demonstration. It shall be the duty of the State Board of Control when said building and school are provided and equipped as above stated to turn it over to the College of Agriculture of West Virginia University for operation and for carrying out of the purposes and intents herein set forth. Any appropriation hereafter made to carry out the provisions and purposes of this act shall be expended through the State Board of Control."

Inwood was selected for the site as an important shipping point in the leading apple-producing county, and also because the growers there had shown a community spirit which commended itself to a committee designated in the act.

Plans for construction were formulated after a trip of inspection to the better apple-packing houses of the East. The best features of these plants were incorporated in the plan of the building, together with certain new features, as for example the roller sorting belt which had not previously been used for apples, although in use in the citrus industry.

The packing plant was completed in 1920, and operations began in that year. A total of 120,000 bushels, the product of 12 orchards, was packed. All of this fruit was graded according to the "federal grades for barreled apples" and through special arrangements with the State Department of Agriculture and the United States Bureau of Agricultural Economics. All fruit sold was first inspected by licensed inspectors, thus originating in 1920 the shipping-point inspection service in the United States.

The Eastern Panhandle as an Apple-Growing District

The importance of the Eastern Panhandle in apple production, and the growth from 1910 to 1925, are shown in Table 1 by the numbers of apple trees in the six leading counties of the district.

Table 1.—*Apple tree facts for the leading counties in the Eastern Panhandle district of West Virginia**

County	Number of trees			Percentage in bearing	
	1910	1920	1925	1920	1925
Berkeley	166,118	629,273	780,736	76.7	72.7
Hampshire	138,249	488,343	419,439	82.1	90.0
Hardy	62,053	124,507	104,268	89.1	88.7
Jefferson	77,537	242,547	270,478	74.6	70.3
Mineral	39,649	145,808	163,881	69.0	90.4
Morgan	64,252	231,384	243,684	71.5	80.1
Total	547,973	1,861,862	1,982,486	77.5	79.3

*Statistical Bulletins 8 and 19 of the U. S. Department of Agriculture.

The very marked increase in number of apple trees for the decade from 1910 to 1920 will be noted. At the end of the decade there were approximately 3.4 times as many trees as at the beginning, and by 1925 the number had increased to approximately 3.6 times the number in 1910. While there has been only a slight increase in the number of apple trees for the district as a whole in the period from 1920 to 1925, the rate of planting has been almost constant year for year, as shown by a comparison of the percentage of trees in bearing.

That the production of the district is essentially for out-of-state consumption is shown by the statistics of carload shipments from the leading shipping points (Table 2). These were obtained from the records of the Bureau of Agricultural Economics*. The shipments

*Data for years preceding 1926 are as published in Statistical Bulletins 8 and 19 of the U. S. Department of Agriculture

are for calendar years, not for the apple-shipping seasons. Not all of the apples grown in a certain year are sold in that year; there is a carry-over to the early months of the next year. As a general rule, the last apples to be sold out of cold storage are shipped to market late in April. The data for seasonal carload shipment records would be slightly different from those in Table 2.

Martinsburg was the leading shipping point for the 8-year period with 6009 carloads, and Inwood was second with 4771 carloads. (Fig. 2.) The importance of Romney as an apple-shipping point is manifest from the fact that it ranks third in the state in that respect.

TABLE 2.—*Rank of the sixteen leading apple-shipping points of the Eastern Panhandle district, based on total carload shipments,* 1920-27, *inclusive*

Station	Rank	Number of carload shipments							
		1920	1921	1922	1923	1924	1925	1926	1927	Total
Martinsburg	1	763	385	511	991	623	685	1041	1010	6009
Inwood	2	546	75	424	892	451	641	953	789	4771
Romney	3	348	4	47	551	507	306	672	1084	3519
Charles Town	4	359	242	67	619	362	338	830	522	3339
North Mountain	5	390	25	156	539	164	203	460	472	2409
Paw Paw	6	102	0	71	416	185	306	415	452	1947
Tabler	7	325	36	188	340	109	245	342	345	1930
Berkeley Springs	8	134	104	0	360	125	54	487	262	1526
Kearneysville	9	218	31	40	343	57	141	261	221	1312
Keyser	10	157	9	46	195	82	70	124	239	916
Ridgeway	11	144	14	36	103	60	145	223	143	868
Hancock	12	8	25	58	188	43	53	228	138	741
Shepherdstown	13	85	29	28	156	27	50	178	109	662
Snyder	14	0	19	33	138	39	170	156	0	555
Shenandoah Jct.	15	35	12	28	125	28	47	145	109	529
Rippon	16	42	59	10	80	58	22	140	32	443

Berkeley County is the leading apple-producing county in the state, just as Frederick County, bordering it, is in Virginia. However, there is no such preponderance of shipments from one point in West Virginia as there is from Winchester, Va. By far the largest number of carloads of apples grown in northern Virginia leave Winchester, while in the West Virginia section there are at least seven major shipping points.

The Packing House and its Relation to Apple Standardization and Grading in West Virginia

In the early days of apple growing little care was given to proper grading until the superior pack of the western growers made better grading essential to successful competition. The packing plant was established to aid in the improvement of such apple grading. It is not alone responsible for the strides which have been made in apple standardization in West Virginia. The State Department of Agriculture, the Bureau of Agricultural Economics of the United States Department of Agriculture, and the West Virginia Horticultural Society have been important agencies in this development. The plant, however, made the original and most effective effort. The standardization of apple grades in West Virginia is therefore associated with it as the original nucleus.

It was realized at the beginning of the fruit-grading work that trained inspectors were necessary, for standardization must be effected by careful inspection. A training school was established at the packing house in 1920. The school has since been in session for about three weeks in every year except 1927. In 1928 about 40 inspectors were given training in the details of inspection, enabling them to inspect apples according to the requirements of the State

FIG. 2.—The yards at Inwood, W. Va., from which 4771 cars of apples were shipped during the 8-year period 1920 to 1927, inclusive. Inwood ranks second among the leading apple-shipping points in West Virginia during this period. The Community Packing House is at the right

Department of Agriculture, in cooperation with the federal Bureau of Agricultural Economics.

Most of the students are residents of West Virginia, but there have been some students from other states. Approximately 135 inspectors have been trained since this phase of the service started.

Study of the principles governing the marketing of apples and the general procedure necessary for successful inspection, lectures by a federal official concerning its practical phases, and actual inspection under observation, constitute the course of instruction. Upon successful completion of this course the student becomes an authorized federal inspector. He then is sent to some shipping point or packing plant to make inspections, and he may also instruct the growers in the requirements and methods of fruit grading. The efforts of the inspectors in teaching the growers proper grading methods are directed to eliminate the frequently occurring trouble of poor grading of apples.

The result of the training school for apple inspectors has been to create a reserve of trained men who are available for work in other states as well as in West Virginia.

Fruit standardization as inaugurated at the Community Packing House has made rapid strides in West Virginia. The number of cars federally inspected in the Eastern Panhandle during the period 1922 to 1928 is as follows: in 1922, 40 cars; 1923, 109 cars; 1924, 317 cars; 1925, 1100 cars; 1926, 3000 cars; 1927, 2600 cars; and 1928, 2300 cars.

In spite of the marked increase in this work, the total number of cars inspected still represents only a small percentage of the total shipments of the whole section. The increase from 40 cars in 1922 to 3000 in 1926 indicates progress, and the prospects for further increase are very favorable. Approximately 60 percent of all the growers have part of their crop inspected,—evidence that the growers realize that the service pays.

How Apples Are Handled Through the Community Packing House

Let us assume that John Doe is a fruit grower near Inwood. In years past he has experienced considerable trouble, as others have, in getting reliable labor to pick and pack his apples. He decides to eliminate the element of chance from his grading tables by joining the Inwood Fruit Growers. His apple-growing business has thus been simplified and he can now concentrate on one main orchard operation—production. He signs a contract and agrees to deliver a definite part or all of his apples to the packing plant. He agrees further that his fruit is to be controlled by a joint committee consisting of representatives from the Growers and the Extension Division of the College of Agriculture—in this instance the superintendent of the packing house. This committee agrees to have fruit graded and inspected according to the state-federal regulations.

John Doe's fruit is handled through the plant and sold on the same basis as all other fruit brought in by the Inwood Fruit Growers. Before reaching the marketing stage let us see how the apples are handled at the packing plant. Six stages describe the progress through the plant:

(1) The apples are delivered in standard lug boxes by truck or other conveyance to the receiving platform. The driver gets a receipt showing the number of boxes of each variety delivered.

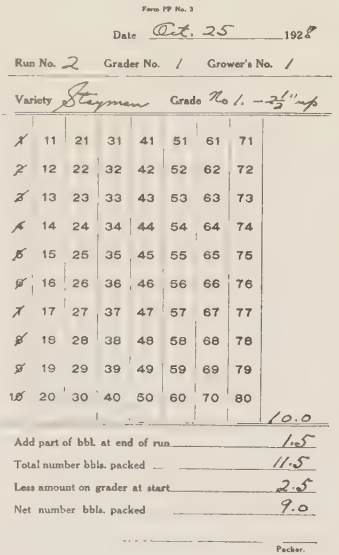
(2) The bookkeeper of the packing plant next determines the net weight of the fruit in the boxes and makes a record of it.

(3) The fruit is then placed on a conveyor and carried to polishing machines, after which it passes over an eliminator which removes all apples too small to be packed or canned. These small apples are known as "ciders". After the weight is recorded these apples are conveyed by belt to a large receiving bin, from where they are hauled by truck to the local vinegar factory or shipped by rail to other factories.

(4) The remaining apples, the bulk of the lot, are now passed over a roller sorting belt where the sorters pick out the fruit unsuitable for packing. This fruit is designated "canners" and is conveyed by belt to boxes outside of the plant and hauled to the local canning plant or shipped to other by-products plants. No record of the weight of "canners" is made at this time, but after a given lot of apples has been graded and packed, the weight of canners is determined by subtracting the total weights of ciders and packed apples from the gross weight.

(5) The fruit has now been carefully sorted, and all defective apples showing insect or disease injuries and any other of the numerous injuries to which fruit is subject, have been removed. The apples are handled with particular care to prevent bruising and are finally packed in barrels or bushel baskets properly labeled according to grade and size. A record of the number of barrels or bushels of each grade and size run over the grader is kept for each variety of apples, and these packages are again converted into net weight of apples. The runner's record of a lot of Stayman is shown in Figure 3. This record is submitted to the bookkeeper.

(6) The grower's identity in connection with his packed apples is designated by a number stamped on the container, and not by his name. As the barrels or bushel baskets are loaded in the cars, a record of these numbers is made. Records are kept on the basis of pounds, and packages are identified by numbers, which simplify the records.


Form PP No. 3

Date Oct. 25 1928

Run No. 2 Grader No. 1 Grower's No. 1

Variety Stayman Grade No 1. -2½" up

1	11	21	31	41	51	61	71
2	12	22	32	42	52	62	72
3	13	23	33	43	53	63	73
4	14	24	34	44	54	64	74
5	15	25	35	45	55	65	75
6	16	26	36	46	56	66	76
7	17	27	37	47	57	67	77
8	18	28	38	48	58	68	78
9	19	29	39	49	59	69	79
10	20	30	40	50	60	70	80

10.0

Add part of bbl. at end of run 1.5

Total number bbls. packed 11.5

Less amount on grader at start 2.5

Net number bbls. packed 9.0

Packer.

FIG. 3.—A runner's record of a lot of Stayman apples that have passed over the grader. This record is prepared for every lot of apples belonging to different growers and is submitted by the runner to the bookkeeper, who files it

SELLING THE FRUIT OF THE INWOOD FRUIT GROWERS

All of the fruit is sold by contract with a national terminal marketing agency. The contract is between the Inwood Fruit Growers and this selling agency. Representatives of the two organizations meet at the beginning of the marketing season to discuss probable marketing conditions, and a number of meetings are held throughout the picking season. Whenever a fruit grower is dissatisfied with prevailing prices he has the privilege of withdrawng his fruit from the general pool and placing it in cold storage to be sold after the normal

marketing period of the apple pools. The sales period of apples belonging to the Inwood Fruit Growers is approximately ten weeks.

All apples are sold on the basis of variety pools throughout the season. The marketing agency returns to the grower an account sale which shows the price at which the fruit was sold, together with all deductions such as freight and handling charges.

The account sale is credited to the variety pool record, and 60 percent of the net proceeds is paid immediately to the fruit growers. The remaining 40 percent is retained to cover the packing costs and handling charges together with the cost of packages. When the final account sale is received for any variety or grade, the pool of this particular variety is closed, whereupon every grower receives credit for the total number of packages delivered to this pool and is paid at the average net price brought by the pool for the season. Full payment is made to all growers before December 1.

In Table 3 is shown the 8-year record of sales for the eight leading varieties handled at Inwood. These returns represent the seasonal pool returns for all fruit and all grades for a certain variety after the selling charge has been deducted. The packing charge and cost of containers must still come out of the returns.

TABLE 3.—*Annual and average returns per barrel of the eight leading apple varieties handled in pools, by rank,* 1920-1927, *inclusive, at the Community Packing House*

Variety	1920	1922*	1923	1924	1925	1926	1927	Average
Stayman	$4.02	$2.98	$2.85	$4.12	$2.47	$2.26	$4.85	$3.36
N. W. Greening	2.89	3.15	1.88	3.29	3.30	3.69	4.38	3.22
Black Twig	3.02	2.74	2.82	3.36	2.68	1.72	5.40	3.10
Winesap	3.63	2.18	2.48	3.20	2.33	2.83	5.04	3.09
Gano	2.64	2.24	1.97	2.93	2.78	2.09	5.28	2.70
Grimes	3.51	...	1.84	2.46	1.86	1.36	4.09	2.52
York	1.60	1.61	1.34	1.94	1.47	2.33	4.66	2.13
Ben Davis	.23	1.81	1.24	1.82	1.37	1.94	3.84	1.75
Average	2.69	2.38	2.05	2.89	2.28	2.28	4.56	

*No crop in 1921 because of freeze.

The returns in Table 3 probably will compare favorably with those of other selling agencies handling the same varieties over the same sales periods. The year 1927 shows by far the best returns. The average return for all the varieties considered in the table was $4.56. The lowest average return occurred in 1923, when only $2.05 was realized. The average returns for 1923 were less than half those for 1927. The highest returns for the eight varieties were for Stayman, which brought an average of $3.36 per barrel, while Ben Davis brought the lowest returns at $1.75 per barrel. The highest return of all varieties in all of the years of the record was for Black Twig in 1927, when $5.40 per barrel was realized. The consistent high returns of Northwestern Greening give this variety high rank.

The Eastern Panhandle of West Virginia, and Frederick County, Virginia, are generally considered York Imperial sections because of the predominance of this variety. In sales at Inwood, however, this variety ranks next to the last. Its profitableness to the fruit grower no doubt lies more in its high yields than in its selling price.

An expression formerly made by growers is, "Year in and year out, Ben Davis will make more money than any other variety." The average returns of only $1.75 per barrel for the 8-year period would seem to contradict this statement. It is the opinion of economists who have studied the leading varieties in West Virginia and Virginia that the members of the Winesap family show a commanding lead over other varieties, a conclusion which is supported by the data in Table 3.

Selling Apples by Brand

The use of brand names to identify apples in the state is growing every year. A few of the well-established brand names for West Virginia apples are "Blue Goose", "Johnny Appleseed", "Mountaineer", "Gold and Blue", "Cumberland Valley", "Worth More", and "Peter Rabbit". The Inwood Fruit Growers' brand "Johnny Appleseed" has been packed since 1920. Two other brands, "Virginia Maid" and "Chef's Choice", were established in 1927. At present all apples packed at the Community Packing House are sold under one of these three brands. "Johnny Appleseed" meets the requirements of a U. S. No. 1 brand, and Fancy. The "Virginia Maid" brand corresponds to a U. S. No. 2, and "Chef's Choice" contains such apples as would be graded "unclassified". The labels of these brands are shown on the cover page and in Figures 4 and 5.

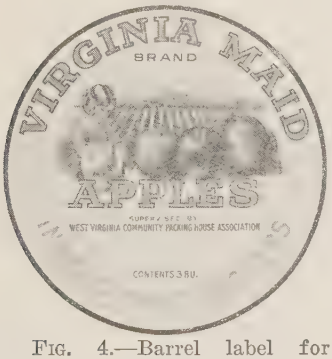


Fig. 4.—Barrel label for "Virginia Maid" brand

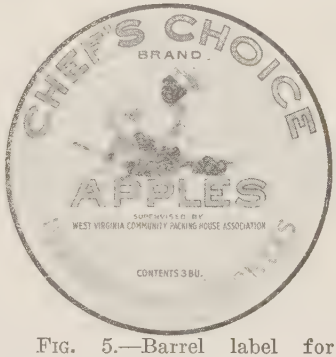


Fig. 5.—Barrel label for "Chef's Choice" brand

(Courtesy *U. S. Department of Agriculture*)

The Inwood Fruit Growers have packed more than 100,000 barrels of "Johnny Appleseed" since 1920: in 1920, 13,628 barrels; 1922, 8,576 bbls.; 1923, 20,941 bbls.; 1924, 7,810 bbls.; 1925, 13,106 bbls.; 1926, 26,467 bbls.; 1927, 6,032 bbls.; 1928, 20,640 bbls.; total, 117,200 bbls.

Of the "Virginia Maid" and "Chef's Choice" brands the following number of barrels were packed: in 1927, 2,000 bbls.; in 1928, 13,760 bbls.; total, 15,760 bbls.

In addition to packing in barrels and baskets on a commercial scale, an increasing quantity of fruit has been packed in standard apple boxes and in special cardboard cartons for demonstrational use in direct-to-consumer marketing. Sufficient work has already been done to demonstrate the feasibility of marketing a considerable portion of the apple crop in this manner.

Observing the work of standardization, growers of other communities have begun to inquire how they, too, might benefit from the work done at the packing house. Under an arrangement with the Growers any group or individual grower desiring to use the "Johnny Appleseed" brand may do so, provided they meet the same conditions as required of the Growers. These conditions are embodied in a set of "Rules Governing the Extension and Use of the Johnny Appleseed Brand." As a matter of protection for the brand name a contract is drawn between the Association and the individual grower.

In 1923 three other groups were organized. These, together with the Inwood Fruit Growers, make up the West Virginia Community Packing House Association.

Packing Costs at the Community Packing Plant

The grower who calculates costs of packing usually considers only labor and materials and, in some instances, light and power. He frequently fails to consider depreciation, interest on investment, and other items essential to correct and complete cost accounting. Furthermore, it is necessary to compare the costs of packing a certain grade of fruit at one packing plant with the same grade and quality packed at another. The quality of the tree run of apples is another necessary consideration.

To explain how the quality of the tree run affects the cost of packing let us consider the case of Mr. A and Mr. B. The former grows a better quality of apples. Let us assume that the cost of handling a bushel of apples through the packing plant is 10c. Mr. A. raises apples of such quality that only four bushels are required to be run over the grader to pack a barrel of No. 1 apples. The cost of packing that barrel is 40c.

Mr. B. grows a much inferior quality of apples. To pack one barrel of No. 1 apples, eight bushels of his tree run fruit are required at a cost of 80c. If Mr. B. realizes the inferior nature of his apples, he may decide to pack two grades and in so doing he may get one barrel of No. 1 and one barrel of "unclassified" apples. He thereby reduces the cost per barrel to 40c. If he decides to pack only one barrel of No. 1 apples and sell the rest as canners he has still another problem, but his cost to pack that one barrel would remain at 80c.

It is evident that all of the factors involved must be considered in order to arrive at a basis for a true comparison of packing costs. Very few apple growers know exactly how much it costs to pack a barrel. If growers would keep such records, adequate comparisons and averages could be drawn.

TABLE 4.—*Daily labor distribution study made at the Community Packing House, August* 30, 1927

Class	Hour Rate	Time (hrs.)	Am't	Receiving Platform		Sorting		Picking Facers		Facing		Running		Heading		Hauling		Labeling		Loading		General	
				Time	Am't	Time	Am't	Time	Am't	Time	Am't	Time	Am't	Time	Am't	Time	Am't	Time	Am't	Time	Am't	Time	Am't
Gen. Mechanic	40c	11	4.40	1	.40	1	.40	1	.40	..	..	1	.40	½	.20	.	..	.	..	.	..	6½	2.60
Header	30	11	3.30	..	..	..	..	..	..	..	..	8¼	2.47	.	..	2¾	.83	.	..	.	..	.	..
Runner	30	11	3.30	..	..	..	..	..	..	..	..	11	3.30	.	..	.	..	.	..	.	..	.	..
Runner	30	10	3.00	..	..	..	..	..	..	..	..	10	3.00	.	..	.	..	.	..	.	..	.	..
Lidder	30	9½	2.85	..	..	..	..	..	..	..	..	..	....	4½	1.35	.	..	5	1.50	.	..	.	..
Runner	27½	9½	2.62	..	..	..	..	..	..	5½	1.52	4	1.10	.	..	.	..	.	..	.	..	.	..
Sorter	25	9½	2.37	..	..	9½	2.37	..	..	..	..	..	....	.	..	.	..	.	..	.	..	.	..
Facer	25	9½	2.37	..	..	..	..	..	..	9½	2.37	..	....	.	..	.	..	.	..	.	..	.	..
Sorter	25	9½	2.37	..	..	3	.75	6½	1.62	..	..	..	....	.	..	.	..	.	..	.	..	.	..
Runner	30	9½	2.85	9½	2.85	..	..	..	..	..	..	..	....	.	..	.	..	.	..	.	..	.	..
Runner	30	10½	3.15	..	..	..	..	2	.60	2	.60	6½	1.95	.	..	.	..	.	..	.	..	.	..
Gen. labor	22½	10	2.25	10	2.25	..	..	..	..	..	..	..	....	.	..	.	..	.	..	.	..	.	..
Sorter	30	10	3.00	..	..	6	1.80	..	..	..	..	4	1.20	.	..	.	..	.	..	.	..	.	..
Sorter	30	5	1.50	..	..	..	..	5	1.50	..	..	..	....	.	..	.	..	.	..	.	..	.	..
Loader	35	10	3.50	..	..	..	..	..	..	..	..	..	....	3	1.05	.	..	.	..	7	2.45	.	..
Facer	25	9½	2.37	..	..	..	..	..	..	9½	2.37	..	....	.	..	.	..	.	..	.	..	.	..
Truck	75	2¾	2.26	..	..	..	..	..	..	..	..	..	....	.	..	2¾	2.26	.	..	.	..	.	..
Ave.	30+	157¾	47.46	20½	5.50	19½	5.32	14½	4.12	26	6.86	25¾	13.42	8	2.60	5½	3.09	5	1.50	7	2.45	6½	2.60

SUMMARY: variety packed, N. W. Greening; total bushels run, 622; total bushels packed, 595; average cost per bushel run, 7½c; average cost per bushel packed, 8c; average cost per hour, 30c; average gross per hr. per man, 4.8 bushels.

Detailed records of the cost of packing both barrels and baskets have been kept by the Inwood Fruit Growers over a period of six years. Costs of packing a barrel of apples have averaged as follows: running, 4c; sorting, 4c; facing, 4c; heading and nailing, 3c; ringtailing, 1c; loading, 3c; coopering, 2c; labeling (lithographs) 1c; total, 22c.

In addition to these charges there are certain items of overhead expense such as replacement of machinery; interest, taxes, and insurance on supplies and for a sinking fund to cover the purchase of an additional tract of land; and other sundry items. All of these vary somewhat from year to year, but over a period of six years they have been found to amount to approximately 10 cents per barrel, in addition to the 22 cents itemized above, making a total packing cost of a barrel of apples at Inwood 32 cents. This cost is almost identical with that of two other well-managed packing houses in the section, at Martinsburg and in Frederick County, Virginia. All three have complete systems of bookkeeping, and records have been kept for a number of years. The average cost of packing at these three plants was 31.1c.

Table 4 presents a one day's study of labor distribution. It serves to show the detail with which packing costs are calculated.

The number of growers who pack their fruit through the packing house has not changed materially from the beginning of operations. There has been a slight fluctuation in the total amount of apples packed because of the size of the crop. The capacity of the plant is approximately 40,000 barrels per season. In years of abnormally large crops a night shift is used. In such years many of the growers have hauled apples on a 20-hour per day basis. It has been found, however, that night operation is uneconomical. The production of a 15-hour packing crew is lower proportionally than that of a 10-hour crew. If the same crew works 15 hours, the efficiency after the 10-hour period becomes appreciably less. When an unexperienced crew is used, the production is also below the standard of the regular 10-hour day crew. Besides, the light bill exceeds the power bill for night operation.

Apple-Packing Records

The packing records of the Community Packing House contain data on more than 25,000,000 pounds of apples. In Tables 5 to 14 is given a detailed analysis of the packing record of the nine leading apple varieties grown in the Inwood section from 1920 to 1927. A considerable range in the percentage of packed apples from year to year is noted. This range is due to seasonal and annual variation in weather which in turn is directly correlated with the severity of infestation by fungous diseases, insect pests, and other causes of injury.

Table 6, presenting a packing record of the Ben Davis apples handled at Inwood for the year 1920 to 1927, inclusive, shows that

in 1927 the percentage of packed fruit was 70, while in 1925 the percentage was only 28.5. In 1924 the crop of Ben Davis was so severely russeted that the entire lot of 54, 366 pounds had to be sold as canners. The influence of seasonal conditions is well illustrated by this variety which is especially susceptible to weather and spray injury. The summary in Table 14 shows that the Ben Davis variety produced the highest percentage of culls and the smallest percentage of packed fruit. The average percentage of packed fruit for Ben Davis during the 8-year period under consideration was only 45.3 percent. The higest percentage in the nine varieties was 85.8 for Delicious.

TABLE 5.—*Amounts of York Imperial apples received and amounts and percentages of packed and cull fruit,* 1920-27, *inclusive, at the Community Packing House*

Year	Pounds received	Pounds packed	Percent packed	Pounds canners	Percent canners	Pounds ciders	Percent ciders
1920	1,664,471	1,049,382	63.0	510,196	30.0	104,893	6.0
1921			No crop due to freezing				
1922	1,499,452	848,445	57.0	486,302	33.0	164,705	10.0
1923	1,820,925	697,476	38.3	807,492	44.3	315,957	17.3
1924	195,730	104,434	53.4	74,441	38.0	16,855	8.6
1925	1,320,371	626,293	47.4	464,870	35.2	229,208	17.4
1926	2,157,525	1,266,260	59.0	852,407	39.0	38,858	2.0
1927	662,521	343,970	51.9	247,781	37.3	70,770	10.8
Total	9,320,995	4,936,260	53.6	3,443,489	36.9	941,246	9.5

TABLE 6.—*Amounts of Ben Davis apples received and amounts and percentages of packed and cull fruit,* 1920-27, *inclusive, at the Community Packing House*

Year	Pounds received	Pounds packed	Percent packed	Pounds canners	Percent canners	Pounds ciders	Percent ciders
1920	467,607	237,780	50.0	207,710	44.0	22,117	5.0
1921			No crop due to freezing				
1922	185,519	116,652	63.0	60,167	32.0	8,700	4.0
1923	2,187,560	994,454	45.5	1,064,810	48.7	128,296	5.8
1924	54,366	Bulked	None	54,366	100.0	None	
1925	1,353,640	385,502	28.5	725,270	53.6	242,868	17.9
1926	872,508	435,667	50.0	243,415	28.0	193,426	22.0
1927	611,501	429,089	70.1	166,441	27.2	15,971	2.7
Total	5,732,701	2,599,144	45.3	2,522,179	43.9	611,378	10.8

The data in Table 14 point to one of the chief sources of loss in apple production in West Virginia and neighboring states. The percentage of apples unfit for packing is much too high for profitable apple-growing. The average percentage of packed apples for the nine leading varieties handled at Inwood during the 8-year period was only 58.5. Improving orchard spraying and cultural practices, to the end that the present packing percentage may be raised to approximately 85 to 90 percent, is a task to which every apple grower in the Eastern Panhandle might well dedicate his best efforts. Marked improvement may be effected by more thorough and timely spraying, together with better cultural practices.

It is common knowledge that in years of average production it is not difficult to sell high-grade apples. The real difficulty lies in the over-production of cull apples. There is little or no profit in raising

TABLE 7.—*Amounts of Grimes Golden apples received and amounts and percentages of packed and cull fruit, 1920-27, inclusive, at the Community Packing House*

Year	Pounds received	Pounds packed	Percent packed	Pounds canners	Percent canners	Pounds ciders	Percent ciders
1920	540,456	366,608	68.0	142,415	26.0	31,433	5.0
1921			No crop due to freezing				
1922			No crop				
1923	614,655	430,325	70.0	101,587	16.5	82,743	13.5
1924	248,325	188,788	76.1	35,813	14.4	23,724	9.5
1925	496,607	256,425	51.6	188,001	37.8	52,181	10.6
1926	1,116,280	838,969	75.0	146,182	13.0	131,129	12.0
1927	24,245	17,766	73.2	5,758	23.7	721	2.1
Total	3,040,568	2,098,881	69.0	619,756	20.3	321,931	10.7

TABLE 8.—*Amounts of N. W. Greening apples received and amounts and percentages of packed and cull fruit, 1920-27, inclusive, at the Community Packing House*

Year	Pounds received	Pounds packed	Percent packed	Pounds canners	Percent canners	Pounds ciders	Percent ciders
1920	319,452	193,275	60.0	102,569	32.0	23,608	7.0
1921			No crop due to freezing				
1922	277,829	190,275	69.0	73,751	26.0	13,803	4.0
1923	403,426	310,427	76.9	72,223	17.9	20,776	9.1
1924	454,818	384,427	84.5	70,391	15.5		
1925	403,830	250,733	62.1	141,111	34.9	11,986	2.9
1926	641,216	440,160	68.0	176,646	28.0	24,410	4.0
1927	285,917	256,677	89.7	22,590	7.8	6,650	2.5
Total	2,786,488	2,025,974	72.7	659,281	23.6	101,233	3.7

TABLE 9.—*Amounts of Stayman apples received and amounts and percentages of packed and cull fruit, 1920-27, inclusive, at the Community Packing House*

Year	Pounds received	Pounds packed	Percent packed	Pounds canners	Percent canners	Pounds ciders	Percent ciders
1920	87,740	60,831	69.0	25,036	28.0	1,873	2.0
1921			No crop due to freezing				
1922	103,505	74,535	72.0	27,250	26.0	1,720	1.0
1923	441,560	329,508	74.8	88,028	10.8	24,024	5.4
1924	230,538	203,451	88.2	19,037	8.2	8,050	3.5
1925	280,276	195,083	69.6	75,550	26.9	9,643	3.5
1926	830,072	542,179	66.0	257,643	30.0	30,250	4.0
1927	230,764	154,922	67.1	72,860	31.5	2,982	1.4
Total	2,204,455	1,560,509	70.7	565,404	25.6	78,542	3.7

TABLE 10.—*Amounts of Black Twig apples received and amounts and percentages of packed and cull fruit, 1920-27, inclusive, at the Community Packing House*

Year	Pounds received	Pounds packed	Percent packed	Pounds canners	Percent canners	Pounds ciders	Percent ciders
1920	60,738	52,407	86.0	7,604	12.0	727	1.0
1921			No crop due to freezing				
1922	1,358	945	69.0	313	23.0	100	7.0
1923	47,520	31,328	65.9	14,716	30.9	1,476	3.2
1924	163,665	145,621	88.9	12,944	7.8	5,100	3.1
1925	34,968	24,302	69.5	10,128	28.9	538	1.6
1926	403,598	270,853	66.0	131,625	32.0	1,120	2.0
1927	29,610	21,983	74.2	7,418	25.0	209	.08
Total	741,457	547,439	73.8	184,748	24.9	9,270	1.3

TABLE 11.—*Amounts of Winesap apples received and amounts and percentages of packed and cull fruit, 1920-27, inclusive, at the Community Packing House*

Year	Pounds received	Pounds packed	Percent packed	Pounds canners	Percent canners	Pounds ciders	Percent ciders
1920	27,774	21,384	77.0	5,629	20.0	761	2.0
1921			No crop due to freezing				
1922	19,758	10,560	54.0	5,448	27.0	3,750	1.8
1923	194,715	141,156	72.5	37,223	19.1	16,336	8.4
1924	97,875	75,660	77.3	15,115	15.4	7,100	7.3
1925	154,928	64,263	41.5	34,003	21.9	56,662	36.6
1926			No crop				
1927	144,786	90,043	62.2	44,663	30.8	10,080	6.9
Total	639,836	403,066	62.9	142,081	20.6	94,689	16.5

TABLE 12.—*Amounts of Gano apples received and amounts and percentages of packed and cull fruit, 1920-27, inclusive, at the Community Packing House*

Year	Pounds received	Pounds packed	Percent packed	Pounds canners	Percent canners	Pounds ciders	Percent ciders
1920	51,103	32,709	64.0	17,625	34.0	769	1.0
1921			No crop due to freezing				
1922	46,333	34,682	75.0	11,201	24.0	450	9.0
1923	169,240	130,054	76.8	18,809	11.1	20,377	12.1
1924	37,800	33,992	89.9	2,708	7.3	1,100	2.8
1925	94,054	83,726	88.9	6,218	6.6	4,110	4.4
1926	116,794	62,155	53.0	34,639	29.0	20,000	18.0
1927	99,736	69,071	69.2	30,070	30.2	595	.06
Total	615,060	446,389	72.5	121,270	19.7	47,401	7.8

TABLE 13.—*Amounts of Delicious apples received and amounts and percentages of packed and cull fruit, 1920-27, inclusive, at the Community Packing House*

Year	Pounds received	Pounds packed	Percent packed	Pounds canners	Percent canners	Pounds ciders	Percent ciders
1920			No Crop				
1921			No crop				
1922			No crop				
1923	32,400	31,267	96.8	955	2.9	178	0.3
1924	28,520	27,032	94.8	1,138	3.9	350	1.3
1925	42,579	32,964	77.4	5,225	12.3	4,390	10.3
1926	105,135	85,092	81.0	13,476	13.0	6,567	6.0
1927	25,440	24,551	96.5	868	3.0	21	0.5
Total	234,074	200,906	85.8	21,662	9.6	11,506	4.6

TABLE 14.—*Summary showing amounts of each of the nine leading varieties of apples received at the Community House, together with amounts and percentages of packed and cull fruits, 1920-27, inclusive*

Variety	Pounds received	Pounds packed	Percent packed	Pounds canners	Percent canners	Pounds ciders	Percent ciders
York	9,320,995	4,936,260	53.6	3,443,489	36.9	941,246	9.5
Ben Davis	5,732,701	2,599,144	45.3	2,522,179	43.9	611,378	10.8
Grimes Golden	3,040,568	2,098,881	69.0	619,756	20.3	321,931	10.7
N. W. Greening	2,786,488	2,025,974	72.7	659,281	23.6	101,233	3.7
Stay-man	2,204,455	1,560,509	70.7	565,404	25.6	78,542	3.7
Black Twig	741,457	547,439	73.8	184,748	24.9	9,270	1.3
Winesap	639,836	403,066	62.9	142,081	20.6	94,689	16.5
Gano	615,060	446,389	72.5	121,270	19.7	47,401	7.8
Delicious	234,074	200,906	85.8	21,662	9.6	11,506	4.6
Total	25,315,634	14,818,568	58.5	8,279,870	32.7	2,217,196	8.8

these. When apple growers have learned to raise a high percentage of high-grade apples (85 to 90 percent of the tree crop), the marketing problem will be on the high road to solution and there will be greater profit in the enterprise. The great development of the apple by-products business in the Cumberland-Shenandoah region is striking proof of the failure of the grower to produce a high percentage of packable fruit.

A study of the packing records together with the sales returns makes possible an estimate of the dollar losses that result from producing apples under the average conditions prevalent in the Shenandoah apple region. The records of the Inwood Fruit Growers are believed to be representative not only of the rest of West Virginia, but also of the other states in the Cumberland-Shenandoah Valley apple section.

During the eight-year period a total of 25,702,664 pounds of common varieties of apples were brought to the Inwood packing house. Only 58.5 percent were packed in containers and the remaining 41.5 percent were hauled to the by-products plants and sold as canners and ciders. Table 15 shows that 78 percent of the culls were canners and 22 percent, ciders.

TABLE 15.—*Summary showing amounts of apples of all varieties received in each year of the 8-year period,* 1920-27, *together with the amounts and percentages of packed and cull fruit for each year and the total for the 8-year period at the Community Packing House*

Year	Total pounds received	Total pounds packed	Percent packed	Total pounds canners	Percent canners	Total pounds ciders	Percent ciders
1920	3,259,151	2,044,346	62.7	1,027,870	31.5	186,835	5.7
1921		No crop due to freezing					
1922	2,149,477	1,286,444	59.8	668,955	30.6	194,078	9.6
1923	6,033,934	3,141,243	52.3	2,232,731	37.2	629,941	10.5
1924	1,520,296	1,171,624	77.0	286,343	18.8	57,424	3.7
1925	4,254,193	1,965,971	46.2	1,673,252	39.4	614,970	14.4
1926	6,280,712	3,970,195	63.2	1,863,024	28.4	447,501	8.4
1927	2,204,901	1,467,897	66.6	626,127	28.4	110,841	5.0
Total 1920-1927	25,702,664	15,047,720	58.5	8,378,402	32.5	2,241,590	8.7

Not all culls are preventable. There is a varying percentage of the tree crop that goes to the cull pile every year for causes beyond the control of the best orchard managers. Such causes as hail pecks, frost russet, sun scald, certain kinds of limb rubs, and fruit spots like York and King David spot, which are the result of an unbalanced physiological condition of the tree, are classed as non-preventable injuries. Such injuries, in addition to the small percentage of disease and insect injury which even the best kind of spraying fails to control, amount to approximately 12.5 percent. With these factors taken into account, a careful grower should pack about 87.5 percent of his total crop. In actual practice some growers in this section have packed more than 90 percent of their crop over a period of years.

The diagram in Figure 6 represents the actual packing percentage and the percentage of culls indicated by the 8-year packing record of the Inwood packing house. Beside this diagram is another, showing the percentage of the tree crop that a careful grower should pack.

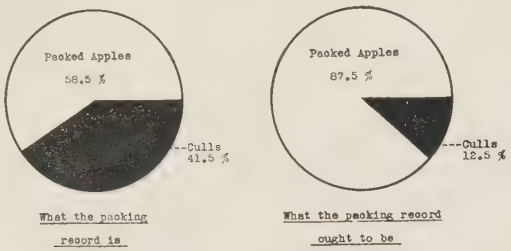


FIG. 6.—Diagrammatic representation of the apple-packing record for all varieties at the West Virginia Community Packing House during the 8-year period, 1920 to 1927, inclusive

Analyzing the money loss resulting from packing 58.5 percent instead of 87.5 percent of the tree crop, we have the following:

SALES RETURNS FOR THE LEADING VARIETIES

The average sales return for the eight leading varieties packed at Inwood during the 8-year period, 1920 to 1927 inclusive, is $2.75 per barrel. A total of approximately 173,668 barrels were hauled to the Inwood plant and of this amount only 58.5 percent were packed. The difference between this figure and 87.5 percent, the amount that should have been packed, is 29 percent, or 50,364 barrels. At $2.75 per barrel the gross loss resulting from raising this quality of apples amounts to $138,500. This is the amount of money that the culls should have returned.

However, 78 percent of these culls were sold as canners and 22 percent as ciders. The average price of canners during this period was approximately 75 cents per hundredweight and 42 cents per hundredweight for ciders. The canners therefore sold for $43,604, and the ciders for $6,887, or a total of $50,491. Since the gross loss mentioned above is $138,500 and the culls returned $50,491, the net loss is $88,009 for the eight-year period.

These figures serve to emphasize that a higher quality of apples, resulting from better orchard management, is essential to a more profitable business.

Records of the causes of cull apples in the Inwood section have been kept over a period of four years. Causes vary between wide limits from year to year. In some years hail and frost injury will cause most of the culls, while in other years diseases and insects will be more important. As a general rule, diseases are more important in

years of heavy and continuous rainfall, while insects are more prevalent in dry, hot years.

Figure 7 represents the causes of cull apples at Inwood. The outstanding fact is that 29 percent of the total 41.5 percent of culls is due to preventable causes. Of these causes, fungous diseases and insect injuries do not produce as much loss as does the lack of good orchard cultural practices. The former cause 12.5 percent, while the latter accounts for 16.5 percent of the culls.

It is not surprising to find a larger percentage of culls caused by poor orchard practice, such as improper pruning, failure to thin, improper fertilization, and carelessness in handling, than from a lack of effective spraying, because spraying has been given especial attention in recent years through the spray service of the University.

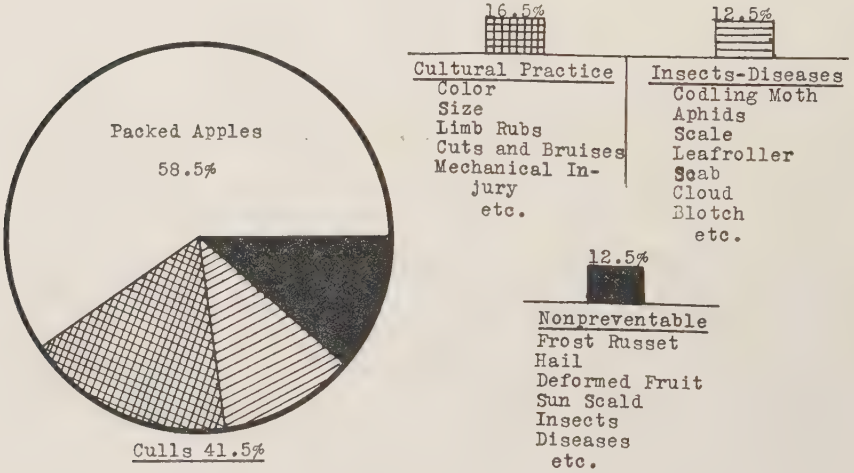


FIG. 7.—Diagrammatic representation of the apple-packing record for all varieties, together with an analysis of the cause of culls at the West Virginia Community Packing House for the 8-year period, 1920 to 1927, inclusive

Failure to produce a higher quality of apples has been due in part to the economic condition of the apple business within the past decade. Growers have been unable to invest money for spray equipment, materials, and labor for pruning and other orchard operations, because of several years of small profit and one of complete crop failure. In recent years the situation has been improving. During 1928 more spray rigs were sold than in the four previous years. Money for fertilizer and orchard operations is now becoming available. It is evident that with a return to favorable prices, greater attention will be given to production methods, and the quality of apples will doubtless be improved.

The Influence of the Packing House

It has been generally recognized that in addition to leadership in apple standardization, the Community Packing House* is largely responsible for the adoption in West Virginia of modern grading machinery and the practice of packing in houses instead of on sorting tables in the orchard. Fifteen years ago grading machines were used in only a few of the better-managed orchards. Most of the packing was done in the orchard and the sorting was done over a table. Today we find only a few of these sorting tables in use and only in the smallest commercial orchards or in the poorly managed larger ones.

The advantages of the grading machine over the sorting table are manifest to anyone who has packed apples. Such machines remove the factor of human error in sizing the apples and have increased the daily output in barrels of packed fruit. The grading machine has been one of the important factors in expediting packing operations and incidentally preventing the losses resulting from heavy dropping and freezing in the latter part of the picking season. (Figure 8 shows a large grading machine in operation at the plant.)

Fig. 8.—A grading machine with a capacity of 700 barrels a day, used for demonstration and regular grading at the Community Packing House
(Courtesy *U. S. Department of Agriculture*)

*Inventory or real estate and equipment as of June 30, 1928, includes the following: 4½ acres of land; the main buildings and laboratory of the packing unit; and the following equipment: Truscott grader, 2 Skinner rolling sorting belts, box elevator, Skinner barrel elevator, cull conveyor, belt roller conveyor, 5 Matthew gravity conveyors, 3 handy barrel presses, 8 electric motors, shafting and belts, auto truck scales, tools, saws, picks, shovels, etc., platform scales, time clock, wheel type roller conveyor, and maul sizing machine; besides the necessary office equipment. The total value of the plant is close to $45,000.

The influence of the packing plant in demonstrating different types of grading machines and in planning packing houses is an important accomplishment to its credit.

APPENDIX

THE C. H. MUSSELMAN COMPANY BY-PRODUCTS PLANT AT INWOOD*

The building, 500 ft. long, was erected in 1920. Operations began in 1921. The building site covers eight acres and adjoins the right of way of the Cumberland Valley division of the Pennsylvania Railroad.

FIG. 9.—Two million pounds of apples stored on the ground prior to the canning operation. At the height of the picking season the capacity of the canning plant is insufficient to handle the supply of canners

The plant employs approximately 375 persons every crop year in a period of operation between September 1 and December 15. The labor comes from a radius of 15 miles around Inwood; about half the supply comes from within the town. A preponderance of female labor is used in this plant because the work requires quickness and dexterity. The company hauls its employees to work and for this purpose uses a number of busses. When busses cannot reach the homes of the workers, the company pays 25 cents for the trip from Martinsburg and immediate vicinity and 30 cents from the mountains 15 miles west of Inwood.

There are three main divisions of the female labor: 150 speckers, 40 peelers, and 22 slicers. All labor is employed on the piece-work

*This plant is described because it is part of the community development at Inwood.

basis; the average wage earned is about $17.50 per week. Some of the speckers who are paid six cents per bucket can turn out 100 buckets per day.

On some days as much as a half million pounds of cull apples is received. The daily capacity of the plant is about 300,000 pounds. When the incoming culls exceed the capacity of the plant, the apples are piled on the ground. A pile of two million pounds of such apples is shown in Figure 9. The average annual tonnage of cull apples handled since the opening of this plant has been about 22,500,000 pounds,—the equivalent of 8,333 carloads or 500,000 bushels. Approximately 273,800 cases of canned apples are produced annually together with 800,000 gallons of cider for the manufacture of vinegar.

This plant packs a solid pack of seed-celled apples and apple sauce in No. 10 tins, and apple-cider vinegar in barrels and assorted sizes of glass containers. The daily capacity of the plant is 25,000 No. 10 cans of solid-pack apples and sauce, 15,000 gallons of cider, and one carload of pomace which is shipped to pectin and jelly manufacturing plants.

Besides the vinegar and canning departments, this plant also packs apples in barrels and bushel baskets. The daily capacity of this department is approximately 340 barrels. A force of 30 persons is employed in this department.

THE WEST VIRGINIA SPRAY SERVICE

The Community Packing House has been the mainspring in the development of apple-grade standardization in West Virginia. The state, however, has gone further in its effort to aid the apple growers. Through various departments of the College of Agriculture and Agricultural Experiment Station it conducts research in insect and disease control. Through the West Virginia Spray Service, managed through the Extension Division, growers are advised when to spray and what materials to use.

In 1922, through the efforts of the extension pathologist, the first service of this kind in the state was given to the growers in the Eastern Panhandle. Letters advising when to begin and end a certain spray, and the amounts and kinds of materials to use, are sent to the growers.

The spray service had its inception in the control of scab, the most damaging apple disease in the few years just before 1922. In that year 75 growers in Berkeley and Jefferson Counties received these spray service letters. So satisfactory was this arrangement that in 1923, 230 growers from 14 counties, the majority of them from the Panhandle, requested this feature. The nature of the spray service was explained by the county agents, through whose efforts, in cooperation with the extension pathologist, it expanded rapidly.

In 1924 the service was extended to 370 growers in 31 counties involving a total of 900,000 bearing apple trees. In 1925 the list grew to 495 apple growers, covering 36 counties and involving 1,000,000 bearing trees. During 1926, 615 growers were served in 46 counties; in 1927 there were 775 growers in 47 counties, while in 1928, 895 growers in 47 counties were served. Today the spray service affects approximately 2,000,000 bearing apple trees. The list of growers as it now stands includes practically every commercial apple grower in the state and a large number of smaller growers who raise fruit for local markets and home use. In 1925 the service was extened to include advice for spraying peaches.

THE INWOOD DEVELOPMENT AS A COMMUNITY COOPERATIVE EFFORT

Before the building of the packing house, Inwood consisted of a few houses and a railroad station noted as an important shipping point for apples. Since the opening of the plant the town has grown rapidly. Seven years ago a few straggling buildings surrounded the packing and by-products plants. Today there are a school, a new community church, and many substantial residences.

Packing plant and by-products plant here constitute a nearly complete and workable apple-handling unit. These plants have given employment to hundreds of persons from the surrounding community. They have been instrumental in retaining for the state large sums of money through the primary processing of a low-grade product which formerly was largely a waste product or else became diverted to points outside the state.

It is not alone in West Virginia that the packing plant is known. Numerous visitors and officials from other states and foreign countries come to the plant to study approved grading and packing equipment and methods of handling apples cooperatively.

Activities at Inwood have been limited chiefly to the apple-packing season. Efforts are now being made to develop a better-rounded program. Cherry trees have been planted in large numbers and plans are being formulated to grow and can vegetables.

Through the cooperation of West Virginia University, its College of Agriculture, Experiment Station, and Extension Division, the State Department of Agriculture, and the Inwood Fruit Growers, the Community Packing House has proved a helpful agency to the apple growers of West Virginia in disseminating information concerning methods of packing, branding, and marketing apples.

ARIZ.UNIV.LIB. FEB 27 1931

BULLETIN 239 JANUARY, 1931

Stationary Spray Systems in West Virginia

BY F. D. CORNELL, JR.

Spring in the Orchard

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

SUMMARY

A plentiful water supply is essential with stationary spraying.

A power unit large enough to maintain proper pressure with some reserve is a necessity.

Elaborate housing is not necessary for successful operation. Ample protection for the equipment, however, is advisable and desirable.

Copper-bearing pipe has certain advantages for use with the stationary spray system.

Main lines vary in size from one to two inches, while laterals should not be less than ¾ inch.

An air chamber of sufficient size in the line is indispensable.

Globe valves and special cut-offs are preferred to gate valves.

Provision for drainage should be made at all low points in the line to prevent difficulties resulting from freezing.

High-pressure hose with a minimum of ½ inch in size is recommended for stationary outfits.

A definite scheme for spraying a block of trees should always be followed if no trees are to be missed.

The trend in development is toward the use of more pipe and fittings, less hose, and a one-man unit. The economy of this plan has been demonstrated. It eliminates delays in the field occasioned through the use of long hose, decreases labor costs and the difficulty of obtaining reliable help, decreases the possibility of missing trees in spraying, and speeds up the spraying operation.

The stationary spray system possesses an advantage in the number of trees it is possible to spray per man hour, as compared with portable sprayers, particularly on systems where a one-man unit is used.

Stationary spray plants are adaptable to every type of topography and are in use now in orchards where portable sprayers could be used only with the greatest difficulty.

The initial cost of the stationary system for orchards of commercial size need be no greater than the cost of complete portable spray equipment for the same orchard.

The advantages of the stationary spray system over portable sprayers in the use of labor, in power requirements, in the elimination of feed costs, in upkeep costs, and in costs of depreciation are economic factors which cannot be disregarded. The per-acre cost of spraying with stationary systems as compared with the portable method is also decidedly in favor of the stationary system.

Stationary Spray Systems in West Virginia

by F. D. CORNELL, Jr.

RADICAL CHANGE marks the attitude toward spraying during the decade just passed. No longer do orchardists ask, "Why should I spray?" but rather, "How can I spray most effectively and economically?" Studies by agricultural experiment stations have brought to light the high percentage of labor ordinarily devoted to spraying. In Maine, for example, it was found that "over four-fifths of the management charge for human labor each year was for pruning, spraying, and dusting operations," and that "over sixty percent of the management charges [for horse labor] each year was for manuring, spraying, and dusting".[1]

Any method whereby this labor charge for spraying could be reduced plainly would be reflected in the net returns. Efficiency of spraying equipment therefore is one of the essentials upon which any successful spray program must be built. Other fundamental considerations are timeliness of spray, effectiveness of spray materials, and thoroughness of application.

The use and development of a stationary spray system for orchards has created widespread interest among orchardists, who see in it a possible solution of the problem of a better means of control of orchard insects and diseases.

RESULTS OF EXPERIMENTAL STUDIES

Advantages of the stationary type of spraying as applied to California conditions are set forth in Bulletin 406 of the California Agricultural Experiment Station. This bulletin describes the individual units of the system and the method of installation. Field observations and results of field tests are also included.

On a large percentage of systems in California electric motors were used as a source of power. The effect of various factors on voltage drop was determined. Tests also showed 1- to 1½-inch mains and ¾- to 1-inch laterals to be most satisfactory. Pressure

[1]MERCHANT, C. H. AN ECONOMIC STUDY OF 93 APPLE FARMS IN OXFORD COUNTY, MAINE, 1924-1927. Maine Agricultural Experiment Station, Bul. 347, pp. 107 and 110.

ACKNOWLEDGMENT

Acknowledgment is made of the assistance of H. L. Crane, formerly associate professor of horticulture, West Virginia University, in making the preliminary survey; of the assistance of C. H. Bruce in obtaining cost records of spraying operations; of the cooperation of F. J. Schneiderhan in furnishing the data on the stationary spray plant on the University Experiment Farm; and of the hearty cooperation of the orchardists without whose assistance this study could not have been made.

tests were made with varying numbers of nozzles to determine the relation between pressure drop and the number of nozzles. Installation costs were found to range from $29.21 to $106.19 per acre, and operating costs from $5.04 to $12.69 per acre for a single application.

Bulletin 212 of the Washington Agricultural Experiment Station describes the units and arrangement of the system. In Washington, as in California, electric power is used extensively. Tests were made on the effect of pressure on atomizing and on the carrying distance of the spray. Data on installation and operating costs are given.

HISTORY OF STATIONARY SPRAYING

Although the stationary spray system was demonstrated as a practical possibility many years ago, its use in eastern orchards has come about rather recently. The idea of a pipe system of spraying was put to a practical test first by Hayward Reed of Sacramento, California, about 1909[2]. From that date until the last decade the development of this type of spray system was very gradual. The use of the stationary plant has since become popular in the western part of the United States, and large numbers of new plants are being installed each year. In the eastern states these plants have not reached such general use. Eastern orchardists, however, are giving evidence of a growing interest in this method of spraying, and an increasing number of new plants is being installed.

STATIONARY SPRAY SYSTEMS IN WEST VIRGINIA

West Virginia orchardists for years have followed the common practice of spraying with portable spray rigs. In the larger orchards several spray rigs, tank wagons, a large number of draft animals, and a large personnel are required to apply a spray. Breakdowns, delays, maintenance, housing of equipment, high feed costs, and high labor costs now cause many orchardists to consider the possibilities of the new stationary systems.

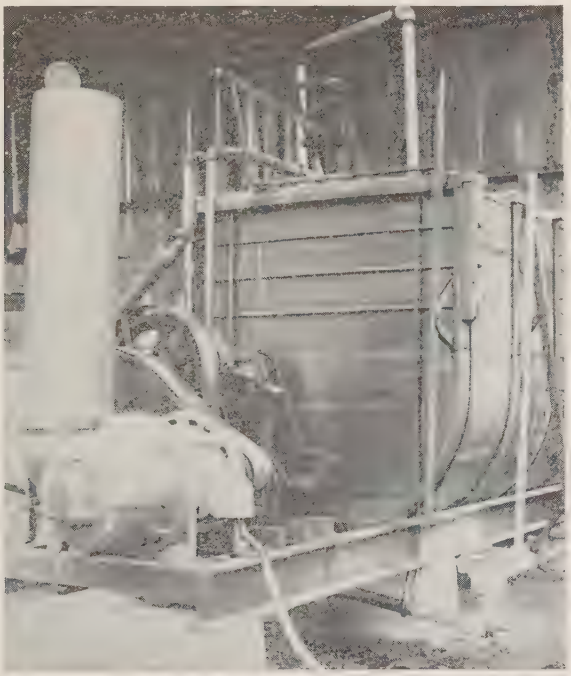
During the past nine years nine orchardists have pioneered the way in West Virginia by installing 13 separate stationary spray systems. Four of these plants were installed and used for the first time in 1929. The first users of stationary systems have gone through the experiences of trial and error in working out the details of the system for West Virginia conditions, and their contribution to our knowledge of this type of spray equipment is noteworthy.

Certain obvious features of the system commend themselves to the orchardist's consideration. Most important of these perhaps is timeliness of spray. In the pink and codling-moth sprays the time limit for effective application is short. With the stationary system these sprays can be applied at the proper time, since wet ground, which often prevents spraying with portable outfits, offers no hindrance to the stationary system.

[2]GARVER, H. L. THE STATIONARY SPRAY PLANT, Washington Agricultural Experiment Station, Bulletin 212, p. 8. 1927.

Economies suggesting themselves to the first users of stationary systems included the savings from spraying with a smaller personnel; greater crop insurance, since the spray could be applied within the proper time limits; elimination of costly draft animals; and lower maintenance costs of equipment.

The purpose of the present study is to furnish West Virginia growers with data and information regarding the details and costs of installation, the handling of the system the year round, and the efficiency and economy of the stationary system as compared with the portable system of spraying for both large and small orchards.



The stationary spray unit on the University Experiment Farm at Kearneysville

This report presents facts and recommendations as obtained from the owners themselves by personal visits during the summer of 1928 and from cost records for 1929. The recommendations are the result of extensive trials with various items of equipment pertaining to the stationary system of spraying. All of the plants studied in the survey of 1928, with one exception, had been installed for at least two spraying seasons.

THE WATER SUPPLY

Owners of the hydrant systems emphasized the necessity of a plentiful water supply. The stationary system requires much water for continuous operation and enough of this must be available to carry on the day's spraying without delay. Quickness in applying the spray and flushing the lines with water both make heavy demands on the water reserve.

The ideal location for the water supply is above the spray plant in order that water can flow to the mixing tanks by gravity. If the water is not so located, it is advisable, where at all feasible, to pump it to a tank or reservoir placed at the desired elevation, rather than to locate the plant near the source of water. The latter method would necessitate pumping the spray liquid up hill under heavy pressure. The opinion of present owners is that the force of gravity should be employed wherever possible. It is advisable too, to install pipes two to three inches in size from the supply to the mixing tanks so that the tanks can be filled quickly.

Central plant of a stationary spray system on a large orchard

LOCATION OF THE PLANT

Most of the orchards in West Virginia are, in part at least, located on well-defined slopes or on rolling land. The main plants of the stationary systems now in use in the state, with two exceptions, are located at high points in the orchards. Thus gravity pressure is brought into play with the result that lower pressures are maintained at the pumps than on level orchards. Another advantage of this plan is that pump and engine or motor are working under lower pressure and load, thus helping to insure longer life and lower maintenance costs.

One owner whose orchards are on opposite slopes has located his plant in the valley between. The pump forces the spray liquid through mains running up both slopes. This plan requires a much higher pressure at the pump than in the cases where gravity is effectively utilized. In general, it is advisable that the plant be located at a high point in the orchard in order to make use of gravity wherever possible.

THE CENTRAL PLANT

The pumping machinery is the most important part of the stationary system because its effectiveness determines in large measure the degree of success obtained from the stationary method of spraying.

The Power Unit

The engine or motor should have sufficient reserve power so that it does not have to work at full capacity at all times. The type of engine may vary greatly, but it must be capable of developing adequate power. There can be found in the plants now successfully operating, power units varying in type and make as follows: three systems operated by steam engines, the engines being used for power and the exhaust steam for cooking the lime sulphur; one Hercules 35 H. P. gasoline engine; one Ford engine; one Stearns-Knight automobile engine; one Hupmobile engine; one 10-20 International tractor; one Edwards engine capable of developing 6 H. P.; and one 7½ H. P. electric motor.

On the only system where there seemed to be much difficulty from delays and breakdowns, a 4 H. P. engine was in use. In computing the power necessary in this instance it was found that at least an 8 H. P. engine would be required for successful operation. It is evident that the power unit is a vital part of the system. In a few cases used automobile engines which had cost as little as $10 seemed to be performing satisfactorily, illustrating that adequate power can often be obtained at a low cost. The employment of such used engines, if replacement parts are readily available, may be a means of considerable saving to growers who are planning to install a hydrant system.

The first stationary spray plant using electric power was installed in the state early in 1930. Where current is available this type of motive power for stationary spray units will likely gain in popularity.

Power Transmission: In most of the systems now in use in West Virginia, power is transmitted by the use of direct gearing. On one small plant a belt is used satisfactorily. On one large plant, in which a pressure of 600 pounds is carried at the pump, power is transmitted also by a belt. Either method of power transmission seems to give satisfactory results, although the more positive gear transmission is preferred. With the electric motor, a silent chain drive is used.

On one of the systems now in use, one of the first, if not the first stationary system in the East, several pumps were tried without success. Finally a well-known concern built a pump according to specifications furnished by the owner of the system. This pump proved very satisfactory. With a few minor changes and replacements which operation proved necessary, it is still operating and shows no sign of serious depreciation after eight years of service. This pump has been improved and refined by the company, and a later model is now in use on three installations.

Most of the leading manufacturers of spray pumps, appreciating the increasing popularity of stationary spray systems, by now have developed highly satisfactory pumps.

Pump and tanks on a large stationary spray system

On the systems now operating in the state there are four Domestic Giant pumps, all of three cylinders. The first model has a 3-inch bore and a 12-inch stroke. The later model, of which three are in use, has a 4-inch bore and a 14-inch stroke. This pump is capable of delivering 80 gallons per minute under 500 pounds of pressure. Two Bean, 3-cylinder spray pumps, delivering 16 gallons per minute under 400 pounds of pressure, are giving complete satisfaction. On one plant a Myers Bulldozer pump delivering 10 to 12 gallons per minute under 300 pounds of pressure is used, and on one plant an old portable spray pump is in use. The latter is a small plant, and although made up almost entirely of cast-off equipment, is serving 60 acres of orchard efficiently. One plant uses a Friend pump and on another plant a Bean pump delivering 25 gallons per minute is used.

Since the pumps in stationary spray systems work under heavy pressures, it is important that they be securely and rigidly anchored to a solid base in order to eliminate vibration. The pump itself, in order to give long service under high pressures, must be very substantially constructed.

The pressures under which the pumps operated at the time of the survey varied from 300 to 600 pounds. The 600-pound pressure was necessary since the spray liquid was pumped up hill, a rise of nearly 400 feet. This gave a pressure at the highest point of about 290 pounds with the gun open. The average pressure carried in the stationary systems was about 400 pounds.

Relief Valves

A reliable relief valve is necessary for proper protection to the system. A relief valve which fails to function properly may cause considerable damage. In one case several of the parts of the system blew up because of failure of the relief valve to operate.*

Strainers

A strainer so constructed that the materials pass up through the screen rather than down is by far the more satisfactory. In a strainer of the upward type the material taken out by the screen tends to fall away from it and settle in the bottom, thus preventing frequent clogging of the screen.

Tanks and Agitators

Several of the tanks in use on stationary systems in West Virginia are wooden tanks taken from old portable sprayers and adapted to use in the stationary system. These are cypress tanks of 200-gallon capacity, except in one case where two such tanks have been placed end to end to make a tank of 400-gallon capacity. The tanks are all equipped with mechanical agitators driven from the pump or the engine. On two recent installations divided tanks, built especially for use with stationary systems, are in use.

On two systems concrete tanks were installed, equipped with mechanical agitators. In building a tank of this type it is important that the corners be filled in and rounded out to prevent spray materials from settling there.

It is advantageous to have the tanks so located with reference to the loading platform that materials may be unloaded from the trucks and emptied with a minimum amount of lifting. The best arrangement seems to be to have the top of the tanks on a level with the platform.

---

*Not enough experimenting has been accomplished to determine definitely which type of relief valve is most reliable.

Housing

The housing of the equipment need not prove an expensive item. The essential features are that it provide protection from the weather for the working parts, and that it be arranged for the greatest ease in mixing and handling materials. Ample space should be provided for working on any part of the equipment.

THE PIPE LINE

The pipe line is a very important part of the stationary system. Experience has taught West Virginia owners much in regard to the details affecting the efficiency of the line.

Kind of Pipe

In every case in the systems studied in the survey of 1928, black iron pipe was used. Cheapness was given as the chief reason for its use. No galvanized pipe was used because the owners felt that the pipe rusts out largely from the inside and that the benefits to be derived from using galvanized pipe did not warrant the additional expense.

One owner was gradually replacing his pipe, as it became necessary, with copper-bearing iron pipe, which is now obtainable at a cost slightly higher than that of black iron. This pipe contains a small percentage of copper which tends to reduce the rate of corrosion. Two systems installed since the date of the survey have used galvanized, copper-bearing pipe throughout. Where it has been tried, it is thought that copper-bearing pipe is worth the additional expense and is a more economical pipe investment in the long run than ordinary black iron pipe.

On one system practically all of the pipe in use had been purchased second-hand. This system was installed in 1921 and most of the pipe was still in use when the survey was made. It showed little evidence of serious depreciation. The fact that satisfactory service may be obtained from used pipe opens another possibility for reducing installation costs. Obviously, if this is tried, the pipe must be in good condition.

Sizes of Pipe Used

For the main lines on the systems studied the following sizes of pipe were in use: 1-inch, 1¼-inch, 1½-inch, and 2-inch. The 2-inch mains were in use on a system where the spray liquid was pumped up hill, a total elevation of 400 feet. The large main in this case was used to reduce loss in pressure due to friction.

For laterals, all owners of stationary systems visited recommended ¾-inch pipe. There were in use for laterals at that time, however, pipes of ⅜-inch, ½-inch, and ¾-inch sizes. The owners who have used pipe as small as ⅜-inch did so at a time when there was little available information on stationary spray plants. The ⅜-inch and ½-inch sizes are slowly being replaced with ¾-inch pipe, although

many laterals of these smaller sizes are still in use. The owners of stationary systems felt that for laterals, 1-inch pipe was too large and expensive, and that ½-inch pipe was too small to give the best results. All recommended that ¾-inch pipe be used for laterals.

Distribution of Mains and Laterals

Because of the topography and irregular layout of orchards in West Virginia, the location and distribution of main lines and laterals is largely an individual problem. In general, at the time of the survey, the laterals were run off the main lines about every 14 tree rows. With the systems now in use, however, this varies from four to 20 tree rows. The mains are run in such a way that the orchard may most easily be covered by the system. On systems installed during the past year more laterals were used, thus making it possible to use a much shorter lead of hose. The tendency in the newer installations is toward the use of more laterals, a shorter lead of hose, and a smaller spray crew.

Laying the Pipe Line

Pipe lines for stationary spraying in West Virginia are laid above ground. This plan hinders cultivation to some extent, and broken pipes are prone to result occasionally, but this method has been preferred to laying the pipe underground since it is cheaper, repairs can be made quickly and easily, and the lines may be laid down or taken up readily. Until recently all lines were laid on the ground. Several systems have now been installed with the pipe lines supported above ground, either by posts or by running the lines through the trees.

In laying the pipe line it is not necessary that the joints be turned up tightly, since the spray materials seal the joints sufficiently. The threads of the pipe should not be leaded in making the connections. One particular method used in attaching the laterals to the main lines seems to have merit. For example, in attaching a lateral to a 1½-inch main, a 1½-inch four-way T is used; this is bushed down to ¾ inch, then a ¾-inch valve is installed and, finally, the lateral pipe. This method of taking off the lateral reduces the friction where the lateral is attached at right angles to the line.

Unions

There should be plenty of unions in the pipe line to facilitate repair as well as taking up or putting down the lines. Ground unions should always be used in this work in order to eliminate the necessity of replacing gaskets frequently.

The Air Chamber

There should be at least one standpipe or air chamber in the line, preferably near the pump. The purpose of the air chamber is to act as an air cushion in the line, smoothing out the flow and pressure in the lines, and so to prevent jarring in the lines. Both commercially

manufactured chambers and home-made ones were found in use. The home-made chambers consisted of a piece of 6-inch casing about six feet long, threaded and capped at both ends, with fittings inserted at one end to attach the chamber to the line, and a pressure gauge fitted in the top cap. In one case, where the line was exceptionally long, two air chambers were in use.

Valves

Valves have caused more trouble than any other part of the pipe line. Owners were of the opinion that gate valves were not satisfactory for hydrant spray work, although many gate valves were in use. Some men had purchased a few high-pressure valves but had found this to be an unnecessary expense. Others were using a cut-off in the lines and found it very satisfactory under test. One orchardist had been using a globe valve with removable seat. There is still some experimenting among growers with different types of valves in an effort to find one better suited to stationary spraying demands. Globe valves and special cut-offs had given the best results at the time of the survey.

One difficulty seemed to be a tendency on the part of the spray crews to close the valves too tightly. Often the result was a leaky valve. The valves tend to become corroded and must be cleaned when the spraying season is over. Where the pipe lines were taken up, one method of handling was to loosen the valves from the seat and drop all of the valves into a barrel of oil. Used crank case oil may be utilized in this manner.

On a recent installation in a neighboring state, where the lines are elevated above ground, globe valves with rising stem are used. In addition the valve is placed with the stem downward so as to eliminate the possibility of materials settling in the valve and hindering opening or closing. The rising stem shows at a glance whether the valve is open or closed. This eliminates the danger of breaking valves by applying unnecessary force when visual examination fails to indicate whether a valve is open or closed.

Care of Pipe Lines Between Sprays

The usual method followed with the stationary systems was to flush them out with clear water a few minutes before quitting time. When the hose men saw clear liquid coming from the last laterals they knew that the system had been flushed out. The pipe line, thus cleared, was left full of clean water until the next day or the next spray.

In cold weather the valves should be raised a little. If there is real danger of freezing, the lines are drained. To accomplish this, there should be a drain plug at all low points in the line.

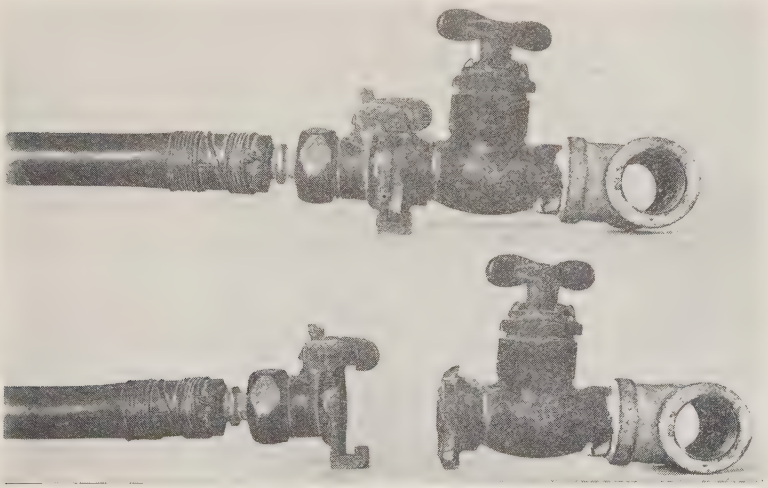
Care of Pipe Line During the Winter

Different methods were employed in handling the pipe lines during the winter. The most common plan was to take up all laterals, after the system had been flushed out with clear water, and

to store the pipe away for the winter. The valves were cared for as has been described (see page 12), and the pipe was usually piled under shelter. One owner, before storing his pipe, dropped it in a trough filled with used crank-case oil. The pipe was then removed, placed on end to drain, and finally stored under cover.

One grower took up no pipe at all. His theory was that the threads, the weakest part of the pipe, are worn out in taking up and putting down the pipe, and that, in addition, there is the labor cost. In handling his system for winter conditions, the valves were lifted off the seats and oil was squirted in the valve after the whole system had been thoroughly washed out with water and drained. The threads and all joints were painted as the pipe lay on the ground, as this was the point where corrosion would take place most rapidly. All pipe lines were then left down until ready to spray the next year. Occasionally a broken pipe resulted from cultivation or travel over it, but its replacement was not difficult or expensive. Some of the pipe handled in this way had been in use for eight years and showed little sign of serious depreciation.

All owners left main lines down all winter. One orchardist painted all mains with red paint. The painting was for preservation, and red was used instead of black so that the lines could easily be seen by those operating cultivating equipment.



A quick coupling device for use with stationary spray systems. Above, hose attached; below, hose detached. The cut-off shown has proved satisfactory for stationary spray work

HOSE AND CONNECTIONS

In all cases but one, owners of stationary spray plants were using 250-foot lengths of hose with each spray crew. The size of hose in use was $\frac{3}{8}$- and $\frac{1}{2}$-inch high-pressure hose. The length of

life of the hose, from the experience of the West Virginia orchardists, was two years. There was a possibility of getting some service out of it the third season. Owners were unanimous in the opinion that nothing smaller than ½-inch hose should be used with the stationary system.

A new development on recent installations has been an increase in the number of laterals, making possible the use of 100- to 150-foot lengths of hose and a reduction in the size of the spray crew.

For repairs and connections the hose man in nearly every case carried a pair of pliers, some soft wire, and hose repair connections. Occasionally a 9-inch pipe wrench was added to this equipment. Patent hose connections were largely discarded because of troubles and delays occasioned by them. The hose in use had cost from 11 to 21 cents per foot, depending upon the number of plys. No hose reels were used in handling the hose.

As a rule very little hose trouble was encountered. In only one instance was trouble of a serious nature reported, the cause being a particularly poor quality hose.

A quick-coupling device for facilitating the speed with which the hose may be attached to and detached from the cut-off has proved very satisfactory.

SPRAY GUNS

The spray gun was in general use with stationary plants in West Virginia in 1928. Owners felt generally that there was room for considerable improvement in guns for use with these systems. All expressed a desire that a more satisfactory gun be developed for stationary spraying conditions, and requested that a study be made of spray guns and rods with a view to developing more satisfactory equipment.

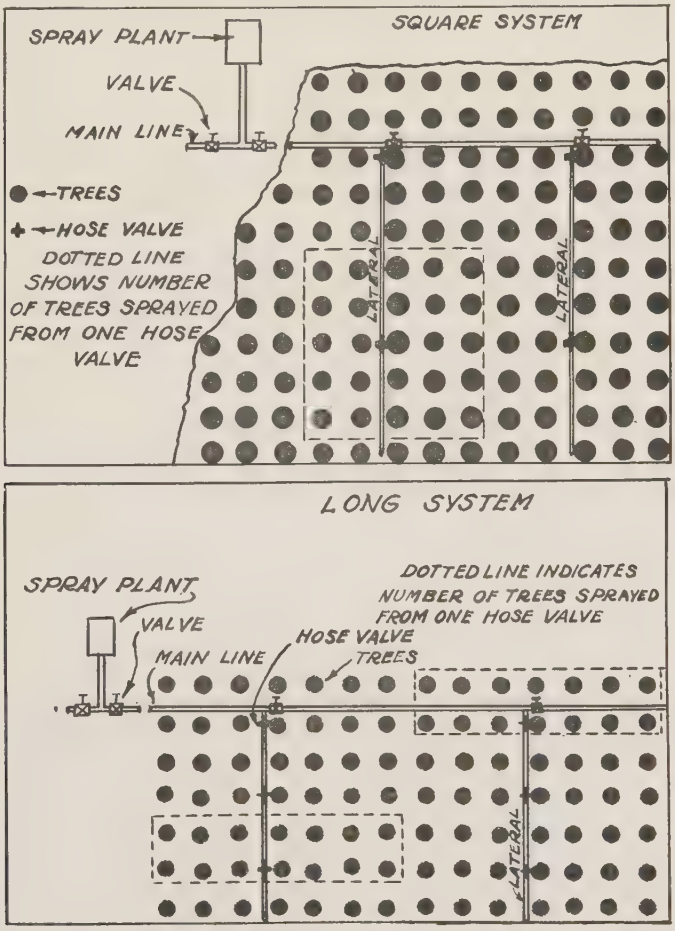
Since the survey was made, various types of rods and guns have been studied and calibrated under stationary conditions, and considerable progress has been made in discovering and developing more efficient equipment. The Virginia Agricultural Experiment Station has recently developed the Virginia nozzle and rod, which it is claimed combines some of the advantages of both the spray gun and the spray rod. Tests with this rod and with other guns and rods were made in connection with the work in stationary spraying on the University Experiment Farm in Jefferson County during the past season (1930). These results are incorporated in pages 27 and 28.

ORGANIZATION OF THE SPRAY CREW

In every case but one, the owners of stationary systems in West Virginia at the time of the survey were using three men in each spray crew: two hose men and one man with the gun. In using 250-foot lengths of hose there seemed to be difficulty in cutting down the size of the crew. One man, however, used a scheme by which two men could handle the work instead of three.

The trend is toward a plan where one man comprises the spray unit instead of three as noted. This scheme is in effect on several installations and seems to be meeting with considerable success. On one plant in the state the length of the leads of hose has been reduced to 100 feet and the size of the crew to one man.

The most common arrangement of spacing the laterals and valves in 1928 was such that a block of 56 trees could be sprayed from



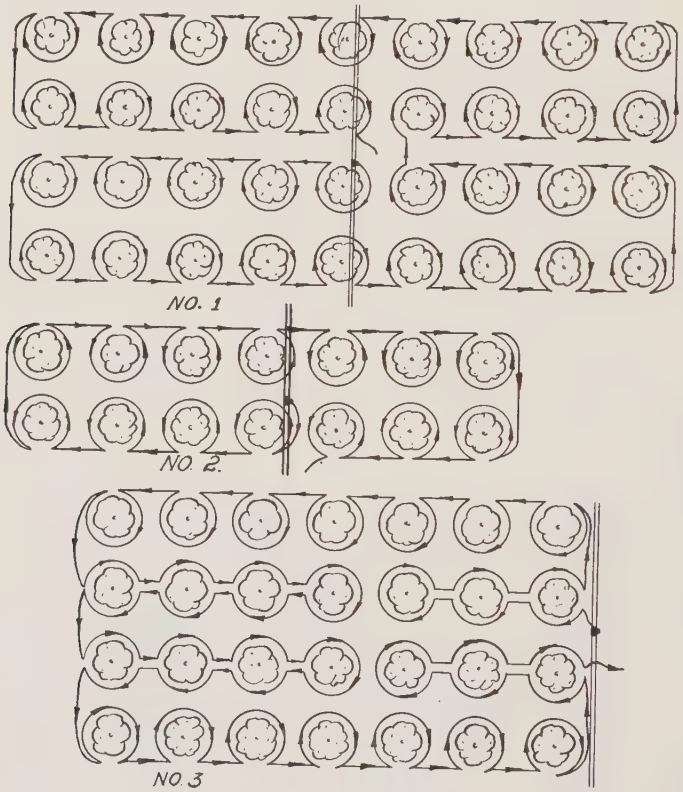
Methods used in piping orchards

one valve. The orchardists visited reported that each crew sprayed an average of about 400 trees per day. Most of the orchardists had the same crews spray the same block of trees throughout the season. In this way they could check on those who were doing careful work, and fix the responsibility for careless work.

In spraying, all followed the practice of first having the man

with the gun get beneath the tree next to the trunk and spray around on the inside, gradually working toward the top. The man then stepped out and walked around the tree, spraying it completely on the outside.

An advantage possessed by the stationary system over the use of portable spray rigs is that the crews in the field are actually spraying about 90 percent of the time. With portable outfits much time is spent in travel and refilling, thus cutting down the actual spraying time per crew.



Systems followed in spraying trees

Some definite scheme for spraying the trees should be followed; in fact, some system is essential if no trees are to be missed. In No. 3 (above) is shown the scheme followed by the grower who used two men in his crew. From the diagram it may be seen that the hose man does not have to drag more than four tree-rows' length of hose at one time. The operation outlined is repeated on the opposite side of the lateral. Other plans for laying out the pipe lines and for spraying blocks of trees are suggested by the diagrams on pages 15 and 16.

ADVANTAGES OF STATIONARY SPRAY SYSTEMS

The advantages of the stationary plant over portable spray rigs, as given by owners of the systems, are:

1. The tree is the unit in this system of spraying.
2. Only one good machinist is needed with this system compared with one for each portable outfit.
3. It is easier to approach a desirable degree of standardization of repair parts.
4. There is much less wear and tear on stationary machinery than on machinery which is hauled over rough ground.
5. Lubricating and adjusting of machinery are more easily cared for.
6. The stationary system makes it possible to spray regardless of the wetness of the soil or of the topography. This makes it possible to apply the spray when most effective. The stationary system can be used with success in orchards where the topography is such that portable spray rigs could not be used at all.
7. Wind does not interfere nearly so much as when spraying with portable rigs.
8. Thorough spraying can be done more quickly than with the portable outfits. The number of trees sprayed per unit of man power is larger than with the portable system.
9. The economy of the system was stressed as a great advantage. Installation and operation of the system are as cheap and sometimes cheaper than outfitting with complete portable equipment. The stationary system does not require the wintering of draft animals.
10. The stationary system may be considered a permanent improvement.
11. The stationary system does not injure cover crops or knock off or bruise fruit as do portable rigs.

DISADVANTAGES OF STATIONARY SPRAY SYSTEMS

The users of stationary systems were very enthusiastic about them and could think of only a few points which could be listed as serious difficulties or disadvantages. The chief disadvantage, and the only one which all growers recognized as such, is given first place in the following list:

1. Any breakdown or tie-up in the system during spraying is rather costly. Much time is lost when men have to be changed from spraying to some other job while repairs are being made.
2. Pipe lines on the ground are prone to be injured by cultivation in the orchard, or by travel over the lines.
3. The cost of changing from the portable to the stationary system of spraying was mentioned by some as a possible disadvantage. This may often prove to be an advantage. Usually the change from portable to stationary methods is made when it is a choice of either purchasing more portable spray rigs or installing the stationary system. In many instances the stationary system, under these circumstances, could be installed for less than the portable rigs and equipment would cost.

THE COST OF SPRAYING WITH STATIONARY PLANTS

It was impossible at the time of the survey to obtain detailed information regarding the costs of spraying with the stationary plants, since none of the owners of such systems had kept detailed records. Consequently, cost records were kept on all of the systems for the 1929 season. The following cost data are taken from these records.

Engine, pump, and tanks on a spray system covering 285 acres

Installation Costs

The first question one asks in considering the stationary spray plant is, "How much does it cost?" Data on plants in operation indicate that there may be considerable variation in the cost of installation.

One owner with 250 acres of orchard, including 12,133 trees, installed his entire equipment for stationary spraying at a cost of $5000. The orchard is so steep that spraying with portable spray rigs would be extremely difficult. The owner estimated that to equip the orchard for portable spraying would cost about $12,000. A smaller stationary plant, serving 40 acres of orchard, was installed complete for slightly less than $1000. A third plant, installed on a 285-acre orchard, cost $2,785.50. Table 1 shows the costs of installing several stationary spray plants on different sizes of orchards.

The costs of installation as given in Table 1 include all items, namely: pump, storage and mixing tanks, power unit, building, hose,

pipe, fittings, connections, labor of installation, etc. Plainly the cost of installation per acre varies considerably. Orchard No. 1, although requiring 2-inch mains, uses 250 feet of hose, thus cutting the cost of laterals somewhat. On orchard No. 2 nearly all of the pipe installed was purchased as used pipe. The cost of housing for the equipment also was comparatively low. It will be noted that the cost of installation on orchard No. 5 was relatively high for the reason that much more pipe was used in this system in order to cut down the size of the spray crew and the length of the leads of hose. Also the construction of new sheds and concrete reservoirs, and the use of copper-bearing pipe throughout, added to the cost.

TABLE 1.—*Cost of installation of seven stationary spray systems in West Virginia*

Orchard number	Installation cost	Number of acres in orchard	Cost per acre
1	$5,000.00	250	$20.00
2	2,785.50	285	9.77
3	998.10	40	24.95
4	3,109.43	98	31.73
5	9,080.34	175	51.88
6	4,557.87	209	21.77
7	4,327.73	70	61.84

TABLE 2.—*Comparison of installation costs of stationary spray systems on three orchards*

Cost items	Orchard number 4 (98 acres)	Orchard number 5 (175 acres)	Orchard number 6 (209 acres)
Variations in pipe line costs			
Pipe	$1274.00	$4934.02	$1955.59
Valves and fittings	463.00	732.02	373.20
Cost per acre	17.72	32.37	11.14
Other items of cost varying with conditions			
Pump	$ 400.00	$ 800.00	$ 550.00
Engine	125.00	*	29.70
Tanks	175.00	60.00	*
Hose and hose connections	80.00	183.39	135.85
Guns or rods	24.00	44.10	8.50
Labor	494.43	849.99	929.65
Building materials for tanks, etc.	*	460.84	532.01
Cost per acre	13.24	13.70	10.45

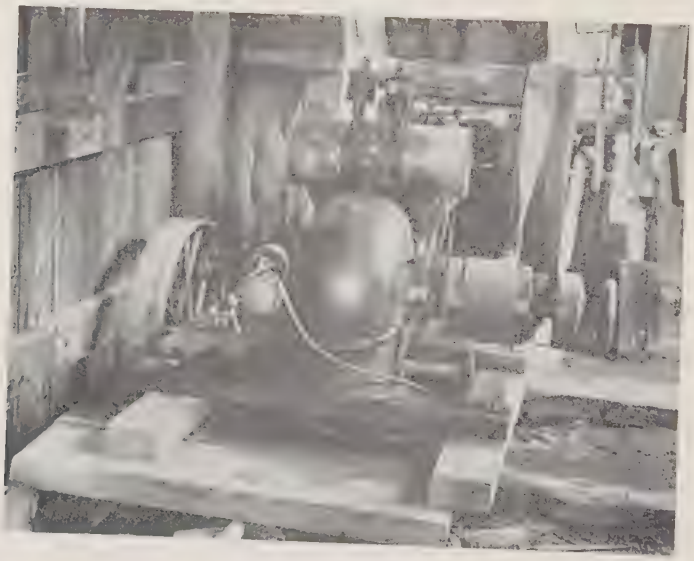
*Used equipment already on hand.

An itemized comparison of the chief items of cost on three systems shows wherein costs of installation may vary. (See Table 2.)

Growers are now realizing the value of installing more laterals, which reduces the labor costs of spraying, as well as the difficulty of obtaining reliable help. Where spray crews can be reduced from two men to one with an investment of approximately $1800 for pipe, as would be possible in one orchard, seven men could be used in the field instead of 14 as at present. The saving would be $21 a day for each day's spraying. On other orchards where three-men crews are used, even more pronounced savings might be effected. This is why plants installed recently show relatively higher pipe costs.

Another factor affecting costs is the rate at which effective spraying can be done. Not the number of trees sprayed per day, but the degree of thoroughness, is a determining factor.

There is no question that just as thorough spraying can be done with portable outfits as with the stationary system. The question is not "Can as thorough spraying be done?" but "Is it done?" The labor obtainable for orchard work is at best often unreliable. It is easier to find six to ten dependable men than twice that number. Here the stationary system possesses an advantage. Besides, in the stationary method of spraying, the man with the gun does not have to adjust his operations to the speed of a team or tractor; neither does he spend time hanging on to keep from being jolted off as a rig passes over rough ground. With the stationary system the tree can be made the unit, and the man with the gun is his own pace-maker.



A plant made largely from cast-off equipment

In a compilation of actual records of 330 days of spraying with several stationary plants the average number of trees sprayed per crew per day was found to be 385. A few of the crews were two-man crews, but the majority were three-man crews. The number of trees sprayed per crew per day ranged from 110 to 1180, depending upon conditions and the age of the trees. From records of 15 days of spraying seven- and eight-year-old trees, it was found that an average of 810 trees were sprayed per 3-man crew per day. These figures concern plants where 250-foot leads of hose were used.

TABLE 3.—*Man hours and labor cost in spraying orchards equipped with stationary spray systems,* 1929.

Orchard number	Acres in orchard	Spraying crews		Manager or foreman		Labor at central plant		Extra labor		Totals		Cost per acre
		Man hours	Cost	Man hours	Cost	Man hours	Cost	Man hours	Cost	Man hours	Cost	
1	250	2440	$717.60	135	$ 64.80	194	$ 63.00	169	$144.48	2938	$989.88	$3.92
2	285	1954	431.22	90	36.00	158	44.40	...	.....	2202	511.62	1.79
4*	98	569	142.25	...	.....	...	.....	...	.....	569	142.25	1.45
6*	209	1952	439.20	...	.....	...	.....	...	.....	1952	439.20	2.10
8	60	348	53.95	...	.....	67	19.20	100	26.00	515	99.15	1.65
9	265	1956	442.48	200	70.00	348	132.05	887	208.98	3391	853.51	3.22
10	235	2752	665.64	155	102.20	284	50.20	...	23.22	3191	841.26	3.58
11*	90	1257	329.35	...	.....	...	.....	...	.....	1257	329.35	3.66

*On orchards 4, 6, and 11, labor costs as obtained were given as one total; consequently they could not be itemized.

TABLE 7.—*Spraying costs on ten orchards using portable sprayers,* 1929

Farm number	Spray labor	Spray machine expense†	Spray material	Total cost to spray	Total man hours	Total horse hours	Total tractor hours	Total number of trees	Total gallons	Gallons per man hour	Total gallons per tree	Number of sprays	Total cost per tree	Cost per tree per spray	Cost per acre
21	$ 85.70	$ 33.40	$ 68.67	$ 187.77	318	238	...	587	8,100	25.4	13.8	6	$.319	$.0533	$12.76
22	189.61	99.07	461.15	749.83	524	692	...	1,800	36,000	68.7	20.0	7	.416	.0595	16.64
23	113.13	40.64	127.90	281.67	437	222	115	1,070	13,600	31.1	12.71	4	.263	.065	10.52
24	109.45	40.70	96.45	246.60	308	228	...	500	11,750	38.1	23.5	5	.493	.098	19.72
25	467.97	147.51	567.36	1,182.84	1,335	1,173	...	3,047	77,350	57.9	25.3	7	.388	.055	15.52
26	298.25	.....	752.35	1,050.60	579	481½	61	5,500	90,550	156.4	18.3	5	*	*	*
27	636.02	.....	747.66	1,383.68	1,304	690	255	*	95,880	73.4	*	5	*	*	*
28	714.26	409.70	632.35	1,756.31	2,231	1,933	...	*	103,350	46.3	*	8	*	*	*
29	448.83	300.25	862.86	1,611.94	1,245	1,500	10	*	102,300	82.1	*	4	*	*	*
30	226.34	.....	472.95	739.29	706	295	115	*	38,700	54.8	*	7	*	*	*

*Data not available.
†Includes depreciation.

Labor Costs With Stationary Spray Systems

Where the charge for labor—an important factor in spraying operations—comprises so large a percentage of cost of man labor as in orchard management, any reduction in this item has a direct bearing on the net returns. Although there has been material reduction in the number of men and the amount of equipment necessary to apply a spray, as a result of using stationary systems, there are possibilities for further reductions in labor requirements. This already is being demonstrated in the most recent installations.

Table 3 shows the man hours required and the cost of labor for the season needed to apply the various sprays in orchards equipped with stationary plants. This includes labor of crews, extra men, help at the central station, foreman, etc.; in fact, all labor items.

The labor shown in Table 3 is for the entire orchard for all sprays for the season. From three to five sprays were applied, but in some cases the complete number of sprays was not applied to all trees. In Table 4 can be seen the total number of trees which these hours of man labor sprayed during the season.

Table 4.—*Quantities of spray materials used during the spraying season on orchards equipped with stationary spray systems*

Orchard number	Size of orchard	Total gallons spray materials used	Total number of trees sprayed	Cost of spray materials	Average gallons per tree per spray
1	250	240,500	31,195	$ *	7.71
2	285	120,751	35,460	*	3.41
4	98	83,600	*	226.22	*
6	209	123,200	*	696.82	*
8	60	15,200	3,121	264.74	4.87
9	265	125,700	31,578	1,354.25	3.98
10	235	78,000	24,085	*	3.24
11	90	62,400	17,532	305.52	3.56

*Data not available.

Table 5.—*Cost and amount of fuel used in spraying with stationary spray systems*

Orchard number	Acres in orchard	Total hours pump was operated	Gasoline		Oil		Coal	
			Gallons	Cost*	Quarts	Cost	Amount	Cost
1	250	194	335	$73.70*	25	$ 6.25		
2	285	158	279	61.38	49	12.25		
6	209	275	226	31.64	44	11.00		
8	60	67	40	8.50	7	1.75		
9	265	175	...	.....	..	.....	10 tons	$45.00
10	235	284	125	31.07	49	12.25		
11	90	151	201	44.22*	46	11.50		

*Estimated cost.

Quantities of Materials Used

The quantity and cost of the spray materials used is the second most important factor entering into spraying costs. Table 4 shows the size of orchard, the quantity of spray materials used, and the total number of trees sprayed, together with the cost of spray materials at the time these data were available.

The average quantity of spray materials applied per tree per spray is not a reliable measure of the thoroughness of the spraying operation. Much depends upon such factors as the age and size of the tree and the nature of the pruning. Without complete information on these factors, the quantity of materials applied per tree per spray can serve merely as an index.

COST OF OPERATING EQUIPMENT EXCLUSIVE OF LABOR

The cost of fuel and oil in operating the spraying systems is shown in Table 5. The repair costs obtained were so slight as to make them negligible. The labor costs in making repairs, therefore, were added to labor costs charged to spraying. Costs of repair replacements were an insignificant item.

PER ACRE COSTS OF SPRAYING WITH STATIONARY SPRAY SYSTEMS

Table 6 shows a summary of the costs of spraying with stationary systems. On not all of the systems were complete cost data available. The costs shown for orchard Nos. 6, 8, 9, and 11, however, indicate the range in costs per acre for the season. A comparison of these costs with the costs per acre for portable spray rigs shown in Table 7 indicates a decided advantage in favor of the stationary system. Such a per-acre saving in cost on a large orchard would soon pay for the investment in a stationary system. (See pages 21 and 23.)

TABLE 6.—*Summary of costs of spraying from stationary spray systems, showing cost per acre where complete data were obtainable,* 1929

Orchard number	Size of orchard	Total labor costs	Total costs of spraying materials	Total costs for fuel and oil	Total cost	Cost per acre†
1	250	$989.88	$ *	$79.95	$ *	$ *
2	285	511.62	*	73.63	*	*
4	98	142.25	226.22	*	*	*
6	209	439.20	696.82	42.64	1178.66	5.63
8	60	99.15	264.74	10.25	374.14	6.24
9	265	853.51	1354.25	45.00	2252.76	8.50
10	235	841.26	*	43.32	*	*
11	90	329.35	305.52	55.72	690.59	7.67

*Complete data not available.
†No charges for depreciation included.

DELAYS

From the records it would appear that the stationary spray system has greatly minimized mechanical difficulties. As an example of causes of delay at the central station, the following are taken from the records kept on a 250-acre orchard for one season:

7 minutes—out of gasoline; 20 minutes—repair leaks in tanks; 15 minutes—belt out of line; 1 hour—adjusting spark on tractor; 1 hour—broken bolt on packing gland; 2 hours—cleaning pipes; 5 hours—cleaning pipes.

On another plant installed in an orchard of comparable size only one hour's delay was charged against the equipment at the central station, and that was caused by dirt in the carburetor.

In the field with the spray crews the chief cause for delays centered about the hose. In the majority of the cases where delays were recorded by the crews, such hindrances were due to bad or broken hose. In only one or two cases was there any delay due to bursted pipe lines.

SPRAYING WITH PORTABLE SPRAYERS

Because records on stationary plants and on orchards equipped with portable sprayers are available for only one spraying season, little attempt has been made to draw conclusions as to the economic efficiency of the two methods of spraying.

The data presented in Table 7 show the costs of spraying on ten orchards equipped with portable sprayers for the 1929 season.

There is considerable variation in the number of gallons of spray applied per man hour, as shown in Table 5. This is further indicated by data obtained on other orchards for shorter periods during the same spraying season. Table 8 shows the number of gallons of spray materials applied per man hour for short periods of spraying on seven orchards equipped with portable spray rigs.

TABLE 8.—*Spraying with portable spray rigs under varying conditions*

Orchard number	Man hours of spraying	Total gallons applied	Gallons per man hour	Kind of equipment used	Number of men
14	103	7,200	69.9	Liqui-duster	2
15	288	21,600	75.0	2 - 300 gal. sprayers	8
16	78	5,100	65.4	1 - 200 gal. sprayer	2
17	36	4,050	112.5	1 - 150 gal. sprayer	1
18	120	11,700	97.5	1 - 300 gal. sprayer	3
19	139	8,350	60.1	2 - 300 gal. sprayers	3
20	220	10,600	48.2	1 - 200 gal. sprayer 1 - 300 gal. sprayer	4

That such variations can and do exist in the quantities of materials that can be applied per hour of man labor indicates that there is room for considerable increase in the efficiency of the spraying operation, largely through improved equipment and better management.

ADAPTABILITY OF THE STATIONARY SPRAYING SYSTEM

Since pumps, engines and motors, pipe, and valves are obtainable in units and sizes to meet almost any need, it would appear that the stationary system is adaptable to almost any set of conditions.

Under some circumstances it has been found possible to combine the stationary and portable methods of spraying by piping the more inaccessible parts of the orchard and using the portable outfit as the pumping station. It is then used as a portable outfit in sections of the orchard where there is no pipe.

THE STATIONARY SPRAY SYSTEM ON THE UNIVERSITY EXPERIMENT FARM AT KEARNEYSVILLE*

During the early months of 1930 the State purchased a 158-acre farm near Kearneysville, Jefferson County, centrally located in the leading fruit-producing region of West Virginia. The farm, known as the University Experiment Farm, was acquired in order that research work on orchard and crops problems confronting the farmers might be carried on under conditions typical of that section of the state.

The first work undertaken at this branch station was the installation of a stationary spray system. Although the system at present serves only 15 acres of orchard, it will eventually be used to spray about 80 acres. A 7½-H. P. electric motor is used for motive power. Thus far this system is the only electrically driven stationary spray plant in the state.

One 600-gallon, two-compartment redwood tank is used in this system. The tank is equipped with special agitators in order to insure the desired degree of agitation. A Super-Giant Bean pump with 3-inch cylinders, having a capacity of 25 gallons per minute, and equipped with an extra large air chamber, is used. The tank, pump, and motor are all mounted on steel sills and are rigidly anchored to a concrete foundation. A silent chain drive is used between the motor and the pump.

The present pipe line consists of 1-inch mains and ¾-inch laterals. The ground on which the lines are laid is fairly level, and pipe larger than one inch was not necessary for the main lines. All of the pipe in use on the system is galvanized, copper-bearing pipe. All of the lines at present are laid on the ground. Thirty-five hundred feet of ¾-inch pipe and 700 feet of 1-inch pipe are used. The laterals are so spaced that it is possible to use a one-man unit. The leads of hose in use are 100 feet long and are easily handled by one man, except when surface growth is extremely thick. The hose is ½-inch, high-pressure hose with special quickly detachable couplings as shown in the figure on page 13.

During the 1930 season six sprays were applied to the 448 trees comprising the present orchard. This required a total of 128 man hours of labor. Because the system was not installed in time, the delayed dormant spray was applied with a portable sprayer, requiring three men and a total of 40 man hours. The remaining five sprays were applied with the stationary system, requiring a total of 88 man hours and 37½ machine hours, as compared with 40 man hours and 25 machine hours for the first spray.

A total of 16,800 gallons of spray was applied to 2688 trees, or 6.25 gallons per tree per spray. The pressures used in spraying varied

*Data were obtained from F. J. Schneiderhan, associate plant pathologist, West Virginia Agricultural Experiment Station.

from 400 to 450 pounds, with most of the spraying being done at 425 pounds. The trees ranged in size as follows: 118 25-year-old trees, 200 ten years old, and 130 six years old.

Table 9 gives the record of the operation of the experimental plant for the 1930 season.

The system was operated during the season a total of 37½ hours. Spraying was delayed 2¾ hours during the entire period for the following causes:

30 minutes—clogged nozzles due to scale from new pipes during first spray.
15 minutes—new spray gun broke and was replaced.
2 hours —replaced defective pressure-release valve.

TABLE 9.—*Record of operation of experimental stationary spray system,* 1930

Name of spray	Total number of men	Total man hours	Average rate per hour	Total pump hours	Number of tanks of spray	Total gallons	Number of men on guns	Pounds pressure	Number of men at plant	Extra men
Delayed* dormant	3	40	.30	25	9½	2800	2	400	None	1
Pink	2	14	.30	7	4	2400	2	425	None	None
Petal fall	2	15	.30	7½	4+	2500	2	425	None	None
Three weeks	2	15	.30	7½	4+	2500	2	450	None	None
Five weeks	3	22	.30	7½	5½	3300	2	425	1	None
Mid-summer	2	22	.30	8	5½	3300	2	425	None	None

*Portable sprayer used.

The average consumption of electricity per spray application was 68 K. W. hours, which at 7½ cents per K. W. H. amounted to $5.10 per spray application. This charge is high and not representative because of the small orchard to be sprayed and because only two men did all of the work. The power cost would have been identical even though five men had sprayed during the same period, since the power used was very largely that of maintaining pressure over a given period. It is obvious that five or six spray men could have worked during the same time in which only two worked. The 25-gallon-per-minute pump was not working at full capacity at any time during the spray season because it was found unnecessary to do so in this small orchard of only 15 acres, which could be sprayed by two men in approximately 7½ hours.*

The purpose of installing the stationary plant of this capacity for such a small orchard was to anticipate the eventual spraying needs when new acreage would be planted, and chiefly also to give

*The spraying was largely of an experimental nature, requiring frequent change of materials and flushing of the system after each material was tried. It is apparent that the labor and cost data are not applicable to ordinary orchard spraying conditions and they are not presented in this bulletin for such purposes.

the apple growers of West Virginia an opportunity to inspect the very latest in stationary spray equipment. This particular outfit is, therefore, of the nature of a model experimental unit which will be changed and will have new equipment added from time to time.

SPRAY GUNS AND RODS FOR USE WITH STATIONARY SPRAY SYSTEMS†

The spray gun is used more extensively with stationary systems in West Virginia than the spray rod. The gun in the hands of an experienced spray man is a very satisfactory implement. Difficulties in operation lie in the fact that the type of spray cone varies as the operator manipulates the cut-off. When a gun is used wide open the result is not spraying, but squirting.

While many orchardists believe that the spray gun has a longer effective drive than the rod, the data in Table 10 indicate otherwise. The improved spray rod which was developed by W. S. Hough of the Virginia Agricultural Experiment Station* satisfies the need of equipment for stationary outfits. This rod has been improved by several commercial concerns. Advantages of improved rods over the spray gun are: the type of spray cone is constant and cannot be altered as in a spray gun; the effective spray drive is longer, thus enabling the operator to spray taller trees from the ground; the spray rod is less liable to misuse and damage than the gun.

Several makes of improved spray rods were tried with the stationary system at the University Experiment Farm during the spray season of 1930. All proved to be satisfactory. For trees averaging 15 feet in height a 6-foot rod was used, while a 9-foot rod was found adequate for the tallest trees in the orchard, some of them 35 feet in height. The nozzles on these rods can be regulated so that any pitch can be obtained. This pitch results in back pressure which exerts a lifting effect and makes handling much easier.

With a one-man unit for each lead of hose the spray man first sprayed upward and outward while standing close to the butt of the tree. The spraying was completed by circling the tree from the outside. When considerable wind was blowing it was found possible to spray most of the tops of trees by taking one or two positions on the windward side and permitting the wind to carry the spray through the top of the tree.

The data in Table 10 show the distance of effective spray drive and the capacity in gallons per minute of different spray implements tested at the University Experiment Farm. By effective spray drive is meant the distance from the gun or rod orifice at which the leaves are turned and sprayed on both surfaces.

---

†Prepared by F. J. SCHNEIDERHAN.

*HOUGH, W. S. ORCHARD SPRAYING AND SPRAY EQUIPMENT. Va. Agr. Expt. Sta. Bul 260, 1928.

The effective spray drive of the two single guns was considerably less than that of the 3- and 4-nozzle rods. Furthermore, the capacity of these single guns is very much less than that of the rods. The 8-nozzle Bean rod is too large for use in an average orchard. This rod has a limited use in hillside orchards when the wind carries the spray down the rows of trees, but when it is used from the ground on small trees, drenching is very likely to follow. The Friend gun has about the same spray drive as the Friend 3-nozzle rod, but since the rod can be of 9- or 12-foot length, it is apparent that it has a greater range than the gun and, in addition, more capacity.

TABLE 10.—*Length of effective spray drive and capacity of different spray implements used at a pressure of* 500 *pounds with a pump capacity of* 25 *gallons per minute on the stationary spray system at the University Experiment Farm,* 1930

Type of spray implement	Spray drive	Capacity per minute
Bean 2-nozzle rod, 2-hole whirl disk	3 feet	3½ gallons
Bean 3-nozzle rod, 6-hole whirl disk	14 feet	6½ gallons
Bean 4-nozzle rod, 6-hole whirl disk	17½ feet	7½ gallons
Bean 8-nozzle rod, 6-hole whirl disk	25 feet	18 gallons
Bean gun	9½ feet	3¾ gallons
Friend 3-nozzle rod, 6-hole whirl disk	12½ feet	5½ gallons
Friend 4-nozzle rod, 6-hole whirl disk	16 feet	7¼ gallons
Friend gun	9½ feet	3¾ gallons
Hardy 4-nozzle rod, 6-hole whirl disk	19 feet	11 gallons
Boyce double gun	21 feet	9 gallons

The Friend 4-nozzle rod has a longer spray drive and greater capacity than the Friend gun. The Hardy 4-nozzle rod, made of duraluminum, proved to be the most satisfactory implement used in this test and in actual orchard spraying at the University Experiment Farm. This rod is very light, has an excellent cut-off, and a greater spray drive and capacity than any of the improved rods tested thus far. The Boyce double gun, according to the data, is much superior to the single gun from the standpoint of spray drive and capacity. A double gun in the hands of an experienced operator is an effective implement when used with a stationary spray system.

In spite of its 21-foot drive it is apparent that every 4-nozzle, 9-foot rod in this test would enable the operator to spray taller trees than with the double gun by reason of the shortness of the latter. As far as visual inspection permitted, the fineness of the spray from all these implements was kept constant during the test.

If the owners of stationary spray outfits would investigate some of the improved spray rods now on the market and compare their effectiveness with that of the spray guns, the result would probably be a more general use of the rod. The gun in the hands of a good spray man can be used effectively on trees up to a height of 20-25 feet, but the rods of various lengths can also be used for trees of that size and in addition, they are more effective for the tallest trees and are less liable to abuse.

ARIZ.UNIV.LIB. MAR 31 1931

Bulletin 240 March, 1931

Effects of Pruning on Growth and Yield of Cherry Trees

BY H. L. CRANE

A View in the Sour-Cherry Pruning Block

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

AGRICULTURAL EXPERIMENT STATION STAFF

JOHN R. TURNER, Ph. D., LL. D., President of the University
F. D. FROMME, Ph. D. .....Dean and Director
GERALD JENNY, M. S., Agricultural Editor....JOHN C. JOHNSTON, Chief Clerk

AGRONOMY AND GENETICS
R. J. Garber, Ph. D.
Agronomist and Geneticist
E. P. Deatrick, Ph. D.
Associate Agronomist
W. H. Pierre, Ph. D.
Associate Agronomist
T. C. McIlvaine, Ph. D.†
Assistant Agronomist
M. M. Hoover, M. S.
Assistant Agronomist
G. G. Pohlman, Ph. D.
Assistant Agronomist
H. K. Rowley, M. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY
E. A. Livesay, D. Sc.
Animal Husbandman
C. V. Wilson, M. S.
Assistant Animal Husbandman
J. H. Longwell, M. A.
Assistant Animal Husbandman
J. H. Rietz, D. V. M. **
Associate Veterinarian
R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman

CHEMISTRY
R. B. Dustman, Ph. D.
Agricultural Chemist
Chas. E. Weakley, Jr., M. A.
Assistant Chemist
L. P. Hansen, Ph. D.
Assistant Chemist
T. B. Leith, M. S.**
Assistant Chemist
I. J. Duncan, B. S.
Assistant in Agricultural Chemistry

DAIRY HUSBANDRY
H. O. Henderson, Ph. D.
Dairy Husbandman
L. M. Thurston, Ph. D.
Assistant Dairy Husbandman
K. S. Morrow, M. S.
Assistant Dairy Husbandman
L. F. Sutton, B. S. Agr.‡
Assistant Dairy Husbandman
R. A. Ackerman, M. S. Agr.
Assistant in Dairy Husbandry

ENTOMOLOGY
L. M. Peairs, Ph. D.
Entomologist
W. E. Rumsey, B. S.**
State Entomologist
Edwin Gould, B. S. Agr.
Assistant in Entomology

FARM ECONOMICS
A. J. Dadisman, Ph. D.
Farm Economist
F. D. Cornell, Jr., M. S.
Assistant Farm Mechanician
W. W. Armentrout, M. S.
Assistant Farm Economist
R. O. Stelzer, B. S.
Assistant in Farm Economics

HOME ECONOMICS
Rachel H. Colwell, M. A.
Home Economist
Hazel C. Cameron, M. A.
Research Specialist in Nutrition

HORTICULTURE
H. E. Knowlton, Ph. D.
Horticulturist
K. C. Westover, M. S. Agr.
Assistant Horticulturist
F. W. Craig, M. S. Agr.**
Assistant Horticulturist
Leif Verner, M. S.
Assistant Horticulturist
M. B. Hoffman, M. S.
Assistant in Horticulture
E. N. McCubbin, M. A.
Assistant in Horticulture
A. P. Dye, M. S. Agr.
Assistant in Horticulture

PLANT PATHOLOGY
C. R. Orton, Ph. D.
Plant Pathologist
Anthony Berg, M. S.
Associate Plant Pathologist
L. H. Leonian, Ph. D.
Associate Plant Pathologist
F. J. Schneiderhan, M. S.
Associate Plant Pathologist
E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY
Horace Atwood, M. S. Agr.
Poultry Husbandman
T. B. Clark, B. S. Agr.
Assistant in Poultry Husbandry

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Experiment Farm, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

Effects of Pruning on the Growth and Yield of Cherry Trees

by H. L. CRANE†

ALTHOUGH long and widely grown in West Virginia, the cherry, both sweet and sour, has remained a fruit of minor importance in this state. In recent years considerable interest has been taken in the production of sour cherries for canning purposes in the Eastern Panhandle. Profitable production of fruit is determined very largely by the yields, and high yields are not consistently obtained without adequate growth of the trees. Since tree growth and yield are closely correlated, the growth and vigor of the trees must be maintained. For this purpose certain practices such as pruning must be employed. In order to study the relations of pruning to the growth and yield of cherry trees an experiment was undertaken in which varying degrees of dormant and summer pruning were used.

HISTORY AND PLAN OF EXPERIMENT

The cherry orchard used in this experiment is located on the Horticulture Farm of the Agricultural Experiment Station at Morgantown. The experiment consisted of seven rows of 30 trees each. Trees numbered one to 15 in each row were of the sour variety Montmorency, and trees 16 to 30 were of the sweet variety Schmidt. The orchard was planted in rows 16 feet wide and the trees 13 feet apart in the rows. One-year-old trees, carefully selected for uniformity of size and vigor, were planted in the spring of 1916. The root systems of the individual trees were pruned as nearly alike as practicable before planting, removing mainly the broken roots and cutting off the rough irregular ends. The tops of all trees were cut off 20 inches from the bud, and the trees were planted so that about two inches of the trunk above the bud was covered.

During the growing season of 1916 all the trees of the Schmidt variety made a satisfactory, uniform growth, but many of the Montmorency trees died, while the growth of the remaining trees was so irregular that all of the latter variety were pulled out and replanted during December. The growth of the replanted Montmorency trees was variable during the growing season of 1917. The following spring (1918) they were severely pruned, leaving only four laterals and a leader. These were cut back to two buds each in an effort to even up the growth. This practice was successful to the extent that

†Resigned November, 1929.

the pruning and training work with the Montmorency trees could begin in the spring of 1919. The pruning and training experiment with the Schmidt variety was started in the spring of 1917.

Eight pruning treatments were used on each variety, as follows:

(1) corrective dormant pruning (a light pruning)
(2) moderate dormant pruning
(3) heavy dormant pruning
(4) early summer pruning, of about the same severity as (2) but done from June 10 to 20
(5) moderate dormant pruning and early summer "pinching". The early summer treatment consisted of pinching back the tips of the laterals to induce branching
(6) light dormant pruning and repeated summer pinching. The repeated summer pinchings were given about the middle of June, middle of July, and first of August, with the idea of causing branching and, in the later pinching, cessation of growth and inducement of fruit-bud formation
(7) late summer pruning, of about the same severity as (2) but done the first to the middle of August
(8) moderate dormant pruning and late summer pinching. The late summer pinching was done in August. Only the growing points were removed in an attempt to check growth and stimulate fruit-bud formation

The early, late, and repeated summer pinching of the growing terminals was continued only during the first five years of the life of the trees. In succeeding years the trees in plots 5, 6, and 8 received only dormant pruning.

Each plot consisted of a single row of trees except in treatments 7 and 8. In these half-rows were used, that is, trees 1 to 8 and 16 to 23 received treatment 7, and trees 9 to 15 and 24 to 30 received treatment 8.

The trees in this experiment were all trained to the modified central leader system, eight scaffold branches being formed on each leader, which was then removed. In the first season three or four scaffold branches were selected in addition to the central leader. These were headed back lightly, moderately, or heavily, depending on severity of the pruning treatment. All other branches were removed. Pruning in the second season consisted in reducing the number of laterals on each main scaffold branch to two, all other shoots being removed. One or two more scaffold branches were left on the central leader, and all the shoots were cut back so as to make a difference in the severity of pruning. During the third and fourth seasons the other scaffold branches were formed. When they were eight in number, the central leader was removed.

The subsequent pruning was of the nature of thinning out the thick places in the trees and removal of interfering or crossing limbs. No heading was practiced after the fourth year except in the heavy

dormant treatment (3), where the heading consisted of cutting back to outside laterals in branches that had grown beyond the general outline of the tree. Each year, after the general framework of the trees was formed, the trees were pruned so that a distinct difference in the thickness of the tree tops of the different plots was evident. The trees which received the early summer (4) and the late summer pruning (7) were pruned as nearly the same as the moderate dormant (2) as was possible. This was very difficult because the foliage present at the time of pruning obscured the branches and shoots.

A system of cultivation and cover crop was used each year until the spring of 1926. The cultivation consisted in shallow plowing in early spring, followed by rather frequent cultivations with a disc or light draft harrow until August, when a cover crop consisting of a mixture of rye and hairy vetch was seeded broadcast. At the time of seeding the cover crop, an application was made of about 300 pounds per acre of 16% superphosphate. No nitrogen-carrying fertilizer was applied to the trees until the spring of 1925, at about the time of blooming, when four pounds of nitrate of soda was applied to each tree. In the spring of 1926 and thereafter the nitrate application was increased to five pounds per tree and was applied at or just before the time of flowering. In the spring of 1926, because of soil erosion and the serious injury to the tree trunks and crotches from low winter temperatures, the orchard was put in sod. Since 1926 the grass has been cut twice each season and allowed to lie where it fell. In the spring of 1928 the sod was top-dressed with 400 pounds of 16% superphosphate per acre. The trees were given the regular spray schedule for cherries. By the spring of 1921 the Schmidt trees had been so severely winter-injured that this part of the experiment was discontinued, and the trees were pulled out.

METHODS USED IN TAKING DATA

Immediately after planting, the circumference of the tree trunks was measured at a point midway between the surface of the soil and the point where the head of the trees was to be formed. This point was marked by painting with white lead and oil a narrow band halfway around the trees. Each spring, with the exception of 1918, the circumference of the tree trunks was measured at this point.

In order to determine the effect of pruning on tree growth the total length of the new shoots produced during the previous growing season was measured in the early spring. The total length of the new shoots produced on each tree was measured in the case of the variety Montmorency for the 5-year period 1917 to 1921, and for the Schmidt for the 5-year period 1916 to 1920. After the new growth was measured the trees were pruned, and the total lengths of the shoots removed were taken. After 1921 the weight of all the wood removed in pruning was used as an index of the severity of the pruning.

TABLE 1.—*Influence of pruning on total length of shoot growth produced per tree during the first five years after planting*

Varieties	Pruning treatment	Total lengths of shoot-growth in feet produced by seasons						Five-year total
		1916	1917	1918	1919	1920	1921	
SCHMIDT	1. Corrective dormant	3.5	17.0	43.8	151.6	165.0		380.9
	2. Moderate dormant	3.6	18.1	44.7	149.1	178.6		394.1
	3. Heavy dormant	2.7	14.2	36.9	118.0	140.3		312.1
	4. Early summer	3.3	16.7	40.0	123.6	130.2		312.8
	5. Moderate dormant and early summer pinching	3.0	21.5	32.0	103.8	121.4		281.7
	6. Light dormant and repeated summer pinching	2.5	13.3	37.2	110.8	123.0		286.8
	7. Late summer	3.9	5.7	31.3	112.6	104.2		257.7
	8. Moderate dormant and late summer pinching	4.2	13.0	34.2	112.0	113.8		277.2
MONTMORENCY	1. Corrective dormant		6.1	31.6	133.9	299.7	775.4	1246.7
	2. Moderate dormant		5.8	28.0	110.1	222.5	516.6	883.0
	3. Heavy dormant		5.9	24.6	105.5	214.4	558.0	908.4
	4. Early summer		6.0	14.9	103.3	186.5	328.7	639.4
	5. Moderate dormant and early summer pinching		8.7	27.0	115.8	211.0	446.2	808.7
	6. Light dormant and repeated summer pinching		9.7	27.0	118.7	187.1	453.0	795.5
	7. Late summer		5.3	31.5	127.5	131.5	498.8	794.6
	8. Moderate dormant and late summer pinching		3.0	19.0	77.2	154.1	451.9	705.2

To obtain a record of the fruiting of the trees, the amount of bloom was estimated for three years in the case of the variety Montmorency. This was discontinued because of winter injury to the buds. The yield of fruit was measured in total number of quarts per tree.

PRESENTATION OF DATA

The data dealing with the effects of the various pruning treatments on the growth of the trees will be considered first, after which the influence of these treatments on the yield of fruit will be presented. In some instances the significance of the data has been determined by Student's method as advocated by Love and Brunson *(5)*. In the tables where this method of calculation has been used the column dealing with odds is important as it gives a fairly accurate measure of the significance of a difference between treatments. Odds greater than 30:1 approach absolute certainty as a limit, while odds much smaller than 30:1 indicate tendencies only.

Tree Growth

The data presented in this report cover tree growth as influenced by various pruning treatments during the first five years of the life of the variety Schmidt and during the first 12 years of the variety Montmorency. The data dealing with the growth are divided into two parts: (a) annual shoot growth, and (b) increase in trunk diameter.

Annual Shoot Growth

The total length of all new shoots formed each year was measured to determine the influence of the various pruning treatments on the growth of the trees. These data are given in Table 1. The Montmorency trees of plot 1, subjected to corrective dormant pruning, made much greater growth than the more severely dormant or summer-pruned trees. The Schmidt trees which were correctively pruned made slightly less total growth during the 5-year period than the trees which were pruned moderately during the dormant season (plot 2); but they made considerably more growth than the trees of the other treatments. The correctively pruned Montmorency trees made more total new growth during the 5-year period than any of the others. These differences first were noticeable in the second year of the experiment.

One of the striking facts brought out by the data of Table 1 is the marked reduction in the growth of the Montmorency trees which were pruned in early summer as compared to those correctively dormant-pruned. This pruning was done in June; consequently many leaves, formed largely at the expense of the food stored the previous year, were removed before they had contributed to the food reserves of the trees. Late summer pruning, likewise, greatly reduced tree growth in both varieties.

Summer pinching of the shoots, regardless of whether it was done in early or late summer or was repeated during the summer, reduced the growth of the trees. This practice seemed to be of little or no aid in forming the framework or in controlling the growth of the trees. The new shoots formed on the correctively pruned trees were more numerous but not as long or stocky as those on the more severely pruned trees. In general the correctively pruned trees had, during and at the end of the first five years after planting, the most symmetrical, compact, and well-formed heads of all the trees under experiment.

TABLE 2.—*Influence of pruning treatment on the average total shoot growth produced by cherry trees**

Varieties	Year	Average total shoot growth							
		Pruning treatment numbers							
		1	2	3	4	5	6	7	8
SCHMIDT	1916	1.00	1.03	.77	.94	.88	.71	1.11	1.20
	1917	1.00	1.06	.83	.98	1.26	.78	.34	.76
	1918	1.00	1.02	.84	.91	.73	.85	.71	.78
	1919	1.00	.98	.77	.82	.68	.73	.74	.74
	1920	1.00	1.08	.85	.79	.74	.75	.63	.69
	Average	1.00	1.06	.81	.89	.85	.76	.71	.83
	Odds		—16:1	4600:1	54:1	7:1	3060:1	25:1	13:1
MONTMORENCY	1917	1.00	.95	.97	.98	1.43	1.59	.87	.49
	1918	1.00	.89	.78	.47	.85	.85	1.00	.60
	1919	1.00	.82	.73	.77	.86	.89	.95	.58
	1920	1.00	.74	.72	.62	.70	.62	.44	.51
	1921	1.00	.67	.72	.42	.58	.58	.64	.58
	Average	1.00	.81	.79	.65	.88	.91	.78	.55
	Odds		94:1	174:1	72:1	3:1	2:1	18:1	>4999:1

*In this table the average annual length of new growth produced on the trees of treatment 1 (corrective dormant) has been taken as unity, and the growth of the trees of the other treatments has been compared with it.

As a measure of the significance of the differences in total length of new shoots formed by the trees in the pruning treatments, the data of Table 1 have been used in the calculation of odds by employing Student's method. In these calculations the annual growth of the trees of the different treatments has been compared to treatment 1 (corrective dormant), which, with one exception, has produced the most growth. This exception is in the case of treatment 2, of the Schmidt variety which had been moderately dormant pruned. Here the odds indicate that these trees made slightly more growth than those which received the corrective pruning. In all other cases the odds indicate that the correctively pruned trees made the most growth. These data are given in Table 2. The wide difference between the growth of the Montmorency trees of treatments 1 and 8 was not due entirely to the pruning but in part to poorer soil. Heavy dormant, moderate dormant, and early summer pruning significantly reduced the growth of the trees as compared to those correctively dormant-pruned. The differences between the other treatments are as a rule not mathematically significant and indicate tendencies only.

It is now well known that pruning young trees reduces their size and growth somewhat in proportion to the severity of the pruning. As an index of the severity of the pruning given the trees two measurements have been used: (a) the length of new wood removed, and (b) the weight of the wood cut off.

Length of Wood Removed. The trees were all trained to the same form with a definite number (8) of main scaffold branches on each tree. For this reason the early pruning of the trees, particularly with the lightly and correctively pruned ones, was more severe in their early life than later, so that at the beginning of this experiment, and until the frameworks of the trees were formed, this type of training had a tendency to give the trees under the various treatments the same start. It was thus possible only during the last two years that measurements of the length of new wood removed in pruning were taken to bring about a distinct difference in the severity of pruning. In the case of the variety Schmidt this was not found possible to the same exent as with the variety Montmorency.

FIG. 1.—Schmidt cherry trees affected by winter injury

The average and total lengths of wood removed per tree during four of the five years are given in Table 3. These data show that with the variety Montmorency a wide difference was effected in the severity of the pruning applied to the trees in the various treatments. The heavily pruned trees (3) had about 60 percent of the wood removed in pruning; the corrective dormant (1) about half as much, or 30 percent. The moderately dormant pruned trees, or plots 2, 5, and 8, pere pruned intermediate in severity between corrective dormant (1) and heavy dormant (3). Such clear-cut differences could not be made with the sweet cherries because of the nature of their growth and the injury following the winter of 1918-1919.

TABLE 3.—*Wood removed in pruning experiments with cherry trees*

Varieties	Pruning treatment	Average length of wood removed in feet per tree by years					Total	Total shoot growth 1917-1920	Percentage of growth removed 1917-1920
		1917	1918	1919	1920	1921			
SCHMIDT	1. Corrective dormant	7.6	15.6	76.8	73.0		173.0	377.4	45.84
	2. Moderate dormant	10.3	20.6	99.5	85.5		215.9	390.5	55.29
	3. Heavy dormant	7.5	20.6	82.9	76.2		187.2	309.4	60.50
	4. Early summer	5.7	22.5	75.3	70.9		174.4	309.5	56.35
	5. Moderate dormant and early summer pinching	13.2	12.8	68.5	58.3		152.8	278.7	54.82
	6. Light dormant and repeated summer pinching	4.1	12.8	61.2	67.7		145.8	284.3	51.28
	7. Late summer	3.1	18.6	78.3	64.7		164.7	253.8	64.89
	8. Moderate dormant and late summer pinching	6.9	19.2	68.0	64.1		158.2	273.0	57.95
MONTMORENCY	1. Corrective dormant		23.3	61.8	106.1	205.9	397.1	1240.6	32.01
	2. Moderate dormant		20.4	71.2	105.0	246.1	442.7	877.2	50.47
	3. Heavy dormant		19.6	80.6	121.5	344.6	566.3	902.5	62.75
	4. Early summer		17.9	84.8	109.5	125.0	337.2	633.4	53.24
	5. Moderate dormant and early summer pinching		19.9	75.8	90.0	237.6	423.3	800.0	52.91
	6. Light dormant and repeated summer pinching		17.8	62.8	52.4	172.7	305.7	785.8	38.90
	7. Late summer		18.4	71.5	90.8	255.6	436.3	789.3	55.28
	8. Moderate dormant and late summer pinching		13.3	49.4	78.4	196.3	337.4	702.2	48.05

TABLE 4.—*Average and total weight of wood removed per tree in pruning Montmorency cherry trees*

Treatment	Average weight in pounds of wood removed by years									Total for nine years	Average per year
	1921	1922	1923	1924	1925	1926	1927	1928	1929		
1. Corrective dormant	1.39	4.03	4.36	5.27	6.95	3.96	5.03	5.24	9.71	45.94	5.10
2. Moderate dormant	1.63	5.22	5.84	4.32	6.37	5.78	4.21	3.30	13.94	50.61	5.62
3. Heavy dormant	2.17	5.94	8.74	6.45	6.75	6.84	6.77	7.90	14.50	66.06	7.34
4. Early summer	1.16	1.81	3.36	3.01	2.55	3.51	5.57	6.01	....	*26.98	3.37
5. Moderate dormant and early summer pinching	1.40	4.30	4.81	4.01	4.64	3.16	5.33	6.83	12.73	47.21	5.25
6. Light dormant and repeated summer pinching	.72	2.96	2.72	2.21	2.96	1.57	2.73	1.64	5.22	22.73	2.53
7. Late summer	2.98	3.11	2.72	1.73	2.66	4.70	3.22	5.00	....	*26.12	3.26
8. Moderate dormant and late summer pinching	2.28	3.51	3.14	3.50	2.82	1.45	2.47	2.03	7.25	28.45	3.16

*Only eight years included as the trees were not pruned in the summer of 1929.

Weight of Wood Removed. After the measurements of the length of wood removed by pruning were discontinued, the trees were pruned so that a difference in thickness or compactnees of the trees under the various treatments existed irrespective of the amount of wood removed. The wood cut from the trees was weighed as indicated in Table 4. Data are included only for the Montmorency, as the Schmidt trees were all removed in the spring of 1921 because of winter injury. (See Fig. 1.) These data show that on the average less wood was removed from the early or late summer-pruned trees (treatments 4 and 7) than from those of the other treatments, with two exceptions: (1) trees of treatment 6 received a light dormant pruning and repeated summer pinching the first five years and light dormant pruning in succeeding years; and (2) trees of treatment 8 received moderate dormant pruning and late summer pinching the first five years. Less wood was removed from the summer-pruned trees because this pruning reduced the growth and severely dwarfed the trees. The continued heavy and moderate dormant pruning also had reduced the size of the trees to such an extent that in some years as much or more wood was removed from the correctively dormant pruned trees. In general, slightly more wood was removed from the moderately dormant pruned trees than from the correctively pruned ones, and much more was removed from the heavily pruned trees.

Diameter of Tree Trunks

Probably the best index of the growth of trees as influenced by certain practices is the year-by-year gain in trunk girth. For this reason the circumference of tree trunks was measured each year during the dormant season at a definite point. From these figures diameter data were calculated in the usual way (Table 5.). Data for the average diameter of the tree trunks at the time of planting are also included. These show that the trees were uniform in size at that time. Even though the difference in severity of pruning of the young trees was not marked, the correctively pruned trees soon developed the largest trunks. The correctively pruned trees of both varieties had the largest trunks by the end of the second year after planting, while the size of the trunks of the other plots failed to increase as rapidly. Summer pruning done in either early or late summer caused the size of the tree trunks to be smaller than a pruning of about the same severity done in the dormant season. The evidence is fairly conclusive that summer pruning is more dwarfing in its effects on the trunks than a similar treatment made during the dormant season. Summer pinching-back of the terminals, even though a small amount of wood and leaves was removed, reduced the growth of the trunks in all instances but one. The responses of both sweet and sour cherries to the varying degrees of dormant and summer pruning and pinchings were very similar. The data show that the largest trunks were secured with young trees by very light dormant pruning.

TABLE 5.—*Comparison of the average trunk diameters of cherry trees pruned in various ways recorded by varieties, treatments, and years*

Varieties	Treatment	Trunk diameters in inches by years												
		*1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929
SCHMIDT	1. Corrective dormant	.45	.61	1.09	1.75	2.56	3.52								
	2. Moderate dormant	.44	.57	1.05	1.72	2.46	3.22								
	3. Heavy dormant	.44	.57	.97	1.58	2.31	2.79								
	4. Early summer	.44	.60	1.00	1.56	2.07	2.51								
	5. Moderate dormant and early summer pinching	.43	.53	.93	1.50	2.25	2.67	Trees removed							
	6. Light dormant and repeated summer pinching	.43	.52	.99	1.63	2.24	2.65								
	7. Late summer	.46	.62	.96	1.55	2.19	2.48								
	8. Moderate dormant and late summer pinching	.43	.52	.89	1.51	2.23	2.61								
MONTMORENCY	1. Corrective dormant	.29	No records made		.93	1.74	2.55	3.51	4.24	4.73	5.13	5.50	6.09	6.67	7.38
	2. Moderate dormant	.28			.79	1.55	2.28	3.21	3.76	4.32	4.59	4.81	5.19	5.50	6.12
	3. Heavy dormant	.31			.88	1.53	2.23	3.10	3.68	4.30	4.60	4.94	5.38	5.77	6.04
	4 Early summer	.28			.78	1.19	1.73	2.47	2.99	3.45	3.72	3.90	4.46	5.13	5.78
	5. Moderate dormant and early summer pinching	.29			.86	1.49	2.19	3.02	3.57	4.03	4.41	4.58	5.18	5.82	6.55
	6. Light dormant and repeated summer pinching	.30			.91	1.52	2.19	2.97	3.53	4.01	4.16	4.31	4.80	5.14	5.65
	7. Late summer	.30			.85	1.47	2.04	284	3.24	3.68	3.89	4.02	4.49	4.84	5.35
	8. Moderate dormant and late summer pinching	.26			.70	1.34	1.92	2.66	3.13	3.50	3.60	3.71	4.16	4.51	5.01

*Diameter of the tree trunks at the time of planting. The Schmidt trees were planted in April, 1916, and the Montmorency in December, 1916.

In order to show more clearly the relation of various types of pruning to the growth of the tree trunks, the average annual increase in diameter has been calculated according to Student's method as given in Table 6. In every case the trunks of trees pruned more severely than those correctively pruned were smaller and, in general, made a smaller annual gain in diameter than those of the lightly pruned trees. These differences are supported by highly significant odds in every one of the Montmorency plots and in three of the Schmidt. Early or late summer pruning of the trees of both varieties reduced the gain in trunk diameter. The data indicate that late summer pruning reduces the growth of the trunks slightly more than a corresponding pruning given in early summer. However, the difference between the early and late summer-pruned trees may be due to the location of the latter on slightly poorer soil. Pinching-back of the terminals before growth ceased, even though only small amounts of wood and leaves were removed, appreciably reduced the amount of gain in diameter of the trunks.

The effect of fruit production on trunk diameter of the variety Montmorency should be pointed out. From the data in Table 6 it will be seen that the annual gain in diameter of the trunks was much smaller during the growing seasons of 1923, 1924, and 1925 than before or after this period. An inspection of the data of Table 8 shows that the crop of 1923 was the first one produced. The two following

Table 6.—*Influence of pruning practices on the average annual increase in trunk diameter (inches) of cherry trees*

Varieties	Year	Increase in trunk diameter in inches							
		Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8
SCHMIDT	1916	.16	.13	.13	.16	.10	.09	.16	.09
	1917	.48	.48	.40	.40	.40	.47	.34	.37
	1918	.66	.67	.61	.56	.57	.64	.59	.62
	1919	.81	.74	.73	.51	.75	.61	.64	.72
	1920*	.96	.76	.48	.44	.42	.41	.29	.38
	Σ	3.07	2.78	2.35	2.07	2.24	2.22	2.02	2.18
	Average	.614	.556	.470	.414	.448	.444	.404	.436
	Odds		7:1	144:1	12:1	177:1	10:1	22:1	161:1
MONTMORENCY	1918**	.64	.51	.57	.50	.57	.61	.55	.44
	1919	.81	.76	.65	.41	.63	.61	.62	.64
	1920	.81	.73	.70	.54	.70	.67	.57	.58
	1921	.96	.93	.87	.74	.83	.78	.80	.74
	1922	.73	.55	.58	.52	.55	.56	.40	.47
	1923	.49	.56	.62	.46	.46	.48	.44	.37
	1924	.40	.27	.30	.27	.38	.15	.21	.10
	1925	.37	.22	.34	.18	.17	.15	.13	.11
	1926	.59	.38	.44	.56	.60	.49	.47	.45
	1927	.58	.31	.39	.67	.64	.34	.35	.35
	1928	.71	.62	.27	.65	.73	.51	.51	.50
	Σ	7.09	5.84	5.73	5.50	6.26	5.35	5.05	4.75
	Average	.645	.531	.530	.500	.569	.486	.459	.432
	Odds		953:1	106:1	389:1	95:1	>9999:1	>9999:1	>9999:1

*The 1920 increase in trunk diameter of the Schmidt was not used in the calculation of Student's Odds because of the winter injury to the trunks of the trees.

**Includes the growth of two seasons, 1917 and 1918.

crops were large. Since 1925 the yield of the trees has been very light because of winter killing of the pistils of the flowers. The crops of 1924 and 1925 were the heaviest borne by the trees up to that time, and it was during these years that the trees made the smallest gains in trunk diameter. These data emphasize the importance of providing good growth conditions during the seasons of heavy crop years.

Bloom and Yield of Fruit

The Schmidt trees were removed before they had attained blooming and bearing age. Records of the blooming of the Montmorency trees were made for five years and the yield of fruit for seven years.

Bloom. The tendency for a tree to bear fruit is better expressed in some instances by the amount of bloom than by the actual fruit produced. In the case of the cherry grown at Morgantown, this was true because of the severe winter killing of the pistils of the flowers. Of course other agencies such as insect pests and diseases may materially affect the set and final yield of fruit. For these reasons the amount of bloom produced by the various trees in each treatment was estimated. It is realized that this method is far from satisfactory, yet a quick method of getting the amount of bloom produced by trees is better than no record at all. Where wide differences exist between trees or treatments the method of estimating has considerable value.

Table 7.—*Influence of various pruning treatments on percentage of Montmorency bloom*

Treatment	Percentage of bloom estimated				
	1921	1922	1923	1924	1925
1. Corrective dormant	58.7	76.8	Practically 100 percent	Practically 100 percent	99.0
2. Moderate dormant	14.2	69.7			94.0
3. Heavy dormant	3.2	51.7			93.0
4. Early summer	17.3	39.6			95.0
5. Moderate dormant and early summer pinching	6.6	74.3			97.0
6. Light dormant and repeated summer pinching	24.2	80.0			95.0
7. Late summer	8.9	64.4			100.0
8. Moderate dormant and late summer pinching	15.0	71.4			100.0

The data for the first five years of bloom of the Montmorency trees are given in Table 7. These data show that the trees produced the first bloom of any importance five years after planting. In the spring of 1921 the correctively pruned trees bloomed by far the heaviest of all the trees under treatment. As the severity of the pruning increased, the amount of bloom decreased. Early or late summer pruning did not increase the amount of bloom produced. Likewise, during the second year of bloom (1922) the correctively or lightly pruned trees (plots 1 and 6) bore more bloom than the trees more severely pruned. The heavy dormant and early summer pruned trees (plots 3 and 4) produced the least bloom of all. In the following years there was practically no difference in the bloom of

the trees. It is understood, however, that due to the larger size of the correctively and lightly pruned trees they had a much larger number of blossoms than the heavily or summer pruned trees.

Yield of Fruit. The spring freezes in the years 1921 and 1922 killed all of the blossoms, and no fruit was produced in these years. Beginning with the crop in 1923 the Montmorency cherry trees have borne some fruit every year. The crops of 1924 and 1925 were fairly good but the last four crops were very light due largely to winter injury to the pistils of the flowers. The yields of fruit were measured in quarts and the data for the seven crop years are given in Table 8.

The data of this table show clearly the effects of summer and dormant pruning on the total yield of sour cherry trees. The correctively dormant pruned trees (plot 1) yielded every year more cherries than the trees under any other treatment. The trees that were pruned more severely in the dormant season only (plots 2 and 3) have had the yield reduced by such treatments; in fact as the severity of the dormant pruning was increased the yield of fruit generally decreased. Both early and late summer pruning markedly reduced the yield. It should be pointed out that both early and late summer pruning, of the same severity as the moderate dormant, reduced the yield by about one half as compared to similar dormant-pruned trees. These data show clearly that summer pruning, either early or late, should be discouraged in sour cherry orchards. Likewise, dormant pruning of greater severity than the corrective pruning is not to be recommended because of the dwarfing of the trees and the small yields of fruit that follow.

The data for the average annual yield of cherries as influenced by the various pruning practices (Table 8) have been reduced to a ratio basis. Student's method of calculating odds has been used in an effort to determine their significance. These data, given in Table 9, show that when the yield of the various plots are compared with that of plot 1 (correctively dormant pruned), every pruning practice employed in these investigations has significantly reduced the yield of fruit. It is also shown that the yield of cherry trees was very materially affected by either summer or dormant pruning of greater severity than the corrective pruning.

Winter Killing of Montmorency Cherry Buds

It has already been pointed out that during the last four years of the experiment the crop of fruit was materially reduced by winter injury of the pistils of the cherry buds. The data of Table 8 show how serious this injury has been as the trees have gained in size and fruit-bearing capacity.

Cherry buds in which the pistils have been killed during late winter or early spring open normally and to casual observation would appear to be normal. However, on close inspection it will be found that varying degrees of pistil injury may be present. In some instances only the stigma may be killed; in others the pistil down to the ovule may be entirely dead. Observations and actual counts in

TABLE 8.—*Influence of various pruning treatments on Montmorency cherry yields*

Treatment	Average total yield in quarts per tree							Total yield in quarts
	1923	1924	1925	1926	1927	1928	1929	
1. Corrective dormant	9.73	29.07	40.77	15.10	18.25	23.40	12.15	148.47
2. Moderate dormant	5.43	19.41	27.25	4.65	13.04	21.25	8.87	99.90
3. Heavy dormant	3.11	20.04	17.55	3.02	5.94	13.40	3.17	66.23
4. Early summer	2.48	11.37	16.22	2.16	4.93	15.75	3.45	56.36
5. Moderate dormant and early summer pinching	4.03	12.45	22.56	4.41	7.94	20.83	3.33	75.55
6. Light dormant and repeated summer pinching	5.09	13.68	19.39	4.03	13.44	23.20	5.60	84.43
7. Late summer	2.93	12.01	15.25	1.02	3.00	7.19	5.38	46.78
8. Moderate dormant and late summer pinching	4.03	7.70	15.06	2.56	1.03	21.83	1.42	53.63

TABLE 10.—*The effect of winter injury* (1924-1925) *to the tree trunks and crotches on the hardiness of the pistils of the flowers of Montmorency cherry* (1925-1926)

Row	Tree	Limb	Remarks	Total number of buds	Total number of flowers	Total number of flowers with pistils killed	Average number of flowers per bud	Percentage of flowers with pistils killed
10	3	1	Normal limb. Heavy pruned	302	646	603	2.14	93.34
10	3	2	Limb completely girdled	267	748	37	2.80	4.95
11	1	1	Pruned in early June—normal limb	106	223	209	2.10	93.72
11	4	1	Pruned in early June—normal limb	172	243	242	1.41	99.59
11	7	1	Pruned in early June—trunk winter injured	163	361	266	2.21	73.68
11	15	1	Limb little affected by winter killing	149	315	249	2.11	79.05
11	15	2	Limb partially girdled by winter killing	235	570	129	2.42	22.63
11	15	3	Limb completely girdled by winter killing	214	501	14	2.34	2.79

the orchard have shown that this injury has, in general, been most severe on the summer-pruned trees followed by the heavy dormant pruning. In general, the practices that have stimulated late growth of the trees or those that have removed their leaf area have resulted in more injury to the pistils of the flowers than where the trees were not forced into late growth by pruning or fertilization treatments or where a maximum leaf area was maintained until late fall.

TABLE 9.—*Influence of pruning treatments on the average total yield of Montmorency cherry trees*

Year	Average yield of cherries*							
	Pruning treatment numbers							
	1	2	3	4	5	6	7	8
1923	1.0	.56	.32	.25	.41	.52	.30	.41
1924	1.0	.67	.69	.39	.43	.47	.41	.26
1925	1.0	.67	.43	.40	.55	.48	.37	.37
1926	1.0	.31	.20	.14	.29	.27	.07	.17
1927	1.0	.71	.33	.27	.44	.74	.16	.06
1928	1.0	.91	.57	.67	.89	.99	.31	.93
1929	1.0	.73	.26	.28	.27	.46	.44	.12
Average	1.0	.651	.400	.343	.469	.561	.294	.331
Odds		810:1	>9999:1	>9999:1	3332:1	755:1	>9999:1	2249:1

*In this table the average annual yield of cherries in quarts per tree produced on the trees of treatment 1 (corrective dormant) has been taken as unity, and the yield of the trees of the other treatments has been compared with it.

There was opportunity in the spring of 1926 to make extended observations on the winter killing of the pistils of Montmorency cherry flowers. The winter of 1924-1925 caused severe injury to tree trunks and crotches of this variety. As a result some trees and particularly some branches of the trees responded in growth and fruit-bud formation as though they had been girdled. At blossoming time in the spring of 1926 counts were made of the number of flower buds formed and the number with pistils killed on normal, partially, and completely girdled limbs from the same and from different trees.

These results, given in Table 10, show that the limbs partially or completely girdled formed the most flower buds per fruit bud. Girdling greatly increased the hardiness of the pistils. The limbs that had been completely girdled by the winter injury had the fewest pistils killed while the trees or limbs which were in the most thrifty and vigorous condition suffered the most injury.

The writer has observed that under West Virginia conditions the pistils of cherry flowers (Montmorency) are often killed by low temperatures in late winter, and that the severity of the injury has been in relation to the vigor or growth of the tree. Sour cherry trees that have been severely pruned or heavily fertilized have been found to bear fruit buds more susceptible to pistil injury than similar trees not stimulated by such practices. This injury probably is due to a difference in the rate of growth and development of the buds during the winter and up to the time the killing temperatures occur. The trees that were stimulated into unusual growth by pruning or fertili-

zation probably have a narrower carbohydrate-nitrogen ratio and a shorter, less profound rest. As a result they make more growth during the warm periods of the winter than trees in which the carbohydrate-nitrogen ratio is wider. This view is supported by the work of Crane *(2)* with the peach and by the fact that the buds on the girdled cherry limbs bloomed several days later than those of the pruned trees.

DISCUSSION

It is unfortunate that the sweet cherries were so severely winter injured that they had to be removed before attaining fruiting age. However, the data for the growth of the Schmidt trees included in this report agree so closely with that of the Montmorency, and the data for the growth and yield of the latter variety are so significant, that it would seem that the effects of certain pruning practices with cherries are clearly defined. This is especially true when it is considered that the results of this experiment substantiate those obtained by Chandler *(1)*, Tukey *(10)*, Rogers *(8)*, and Shoemaker *(9)*.

Chandler *(1)* as a result of his experiments in pruning various fruits says in regard to pruning sweet cherries, "It was clear that to prune a sweet-cherry tree to any form different from that to which it would naturally grow is more of a dwarfing process than with any other fruit tree under experiment. It must delay fruiting proportionately." In his experiments with sour cherries he found that the early pruning necessary to form open-headed trees dwarfed them and reduced the yield as compared to trees allowed to grow normally. In summarizing his results he was of the opinion that cherry trees should receive very little pruning until they were eight or nine years old. The data presented in this report of the West Virginia experiments substantiate this opinion.

Tukey *(10)* working with old Montmorency, English Morello, and Early Richmond trees which had grown tall, attempted to lower the tops by pruning and to increase the vigor of the trees by nitrate of soda applications. The pruning checked the total tree growth the first season and at the end of three years the growth of the pruned trees did not equal that of the unpruned ones. However, where nitrogen was also applied, the pruned tree at the end of the third season had recovered and appeared more vigorous than untreated trees. The yield of fruit on the pruned trees was much less in the first season following the pruning and failed to equal the yield of the untreated trees at the end of the third season. However, when the trees were fertilized in addition to the pruning, by the third season the yield was equal to or greater than that of the untreated trees. He presents data to show that pruning increases the size of the cherries.

Rogers *(8)* in a report on a sour cherry orchard says of trees which had been rather severely pruned, "During their non-bearing period. . . . their bearing was delayed and their early crops materially

and unnecessarily reduced." The records show that the severely pruned trees were from three to five years behind lightly pruned trees in fruit production.

Shoemaker *(9)* in reporting on cherry pruning experiments in Ohio with trees planted in 1914, some of which were very lightly pruned and others heavily pruned, presents data that show the yield of the lightly pruned trees for the five crop years of 1923 to 1927, inclusive, to be greater than that of the heavily pruned trees. He says, "The very light pruning, however, led in course of time to very thick, bushy conditions, and the fruit ripened unevenly, so that several pickings were required in 1926 and 1927."

From the data presented in this report and from the experimental evidence of other workers cited above, it seems clear that cherry trees during the vegetative or non-bearing period should receive only sufficient pruning to train the trees to a modified central leader tree. The debudding method of starting the young trees as recommended by Fagan *(3)* and by Fagan and Anthony *(4)* has proved so successful with apples that it would seem that a modification of this method could be advantageously used in starting young cherry orchards and thus eliminate to a large extent the pruning necessary to shape the tree.

The correctively pruned trees in this experiment have been pruned lightly each year, and although the trees are somewhat bushy and thick, no appreciable differences have been observed in the time of ripening of the fruit on these trees as compared to those on the more severely pruned ones. This, of course, may have been due to the very light crops produced during the last four years. As the trees become older more severe pruning may be necessary to keep the trees open. Roberts *(6)* found the open-head tree to be desirable in order to increase the number of spurs that remain alive. He also found that the spur fruit buds are less susceptible to winter injury than those on terminals, which is in accord with the observations made in West Virginia. He gives evidence in favor of renewal-pruning for old cherry trees, as this not only results in the production of more buds on spurs but also increases the growth and vigor of the twigs. Roberts *(7)* in a later report gives some data which indicate that such pruning may increase the yield of fruit on older trees.

The data presented in this report show clearly the severe dwarfing effect of summer and heavier than corrective dormant pruning on the tree growth of sour cherry trees. Yield was also greatly reduced. The data likewise show that summer pruning, either early or late, decreased yield as compared to trees pruned with equal severity in the dormant season. This reduction in tree growth and yield of fruit following summer pruning apparently is due to the removal of the leaves before they have made their contribution to the food supply of the tree. This would emphasize the great importance of maintaining during the summer and early fall the maximum area of leaves capable of functioning photosynthetically.

Tukey *(10)* points out that severe pruning practices increased the size of the cherries, but Rogers *(8)* says that exceptionally large, sour cherries are not particularly wanted by the canners. In the West Virginia experiments the fruits borne on the correctively pruned trees, as far as observed, were very slightly, if at all, smaller than those produced on the more severely pruned trees. This may have been due to the small crops of fruit borne during the last four years of the experiment.

CONCLUSIONS

Young correctively pruned sour cherry trees make more shoot growth and larger gains in trunk diameter, come into bearing earlier, and produce heavier crops than similar trees more severely pruned. Summer pruning, regardless of the time during the summer when it is done, has the effect of severely dwarfing tree growth and reducing the yield, as compared to dormant pruned trees which had been pruned equally as severely.

LITERATURE CITED

1. Chandler, W. H.
   RESULTS OF SOME EXPERIMENTS IN PRUNING FRUIT TREES. Cornell Univ. Agr. Exp. Sta. Bul. 415. 1923.
2. Crane, H. L.
   PHYSIOLOGICAL INVESTIGATIONS ON THE RESISTANCE OF FRUIT BUDS TO FREEZING TEMPERATURES. W. Va. Agr. Exp. Sta. Bul. 236. 1930.
3. Fagan, F. N.
   EFFECT OF DEBUDDING IN THE FORMATION OF SCAFFOLD BRANCHES UPON LEAF SURFACE AND TERMINAL GROWTH. Proc. Amer. Soc. Hort. Sci. 21:12-13. 1924.
4. Fagan, F. N., and Anthony, R. D.
   TRAINING AND PRUNING APPLE TREES. Penn. Agr. Exp. Sta. Bul. 224. 1928.
5. Love, H. H., and Brunson, A. M.
   STUDENT'S METHOD FOR INTERPRETING PAIRED EXPERIMENTS. Jour. Amer. Soc. Agron. 16:60-68. 1924.
6. Roberts, R. H.
   PRUNE THE CHERRY TREE. Wis. Agr. Exp. Sta. Bul. 298. 1919.
7. ———————
   BETTER CHERRY YIELDS IN WISCONSIN. Wis. Agr. Exp. Sta. Bul. 344. 1922.
8. Rogers, A. J. Jr.
   STUDIES IN ORCHARD MANAGEMENT, WITH SPECIAL REFERENCE TO CHERRY PRODUCTION. Michigan Agr. Exp. Sta. Spec. Bul. 166. 1927.
9. Shoemaker, J. S.
   PRUNING CHERRY TREES. FRUITS AND GARDENS. 27: No. 1, 8-9. 1929.
10. Tukey, H. B.
    RESPONSES OF THE SOUR CHERRY TO FERTILIZERS AND TO PRUNING IN THE HUDSON RIVER VALLEY. N. Y. Agr. Exp. Sta. Bul. 541. 1927.

.172
51
1

BULLETIN 241 APRIL, 1931

Four-H Club Work in West Virginia

BY T. L. HARRIS

Livestock—A Popular 4-H Enterprise

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

A 4-H Camp Among the Hills

*Four-H Club Work in West Virginia**

by T. L. HARRIS

I. INTRODUCTION

SINCE the passage of the Smith-Lever law in 1914, boys' and girls' 4-H club work has developed rapidly in farming communities of the United States, having become an important phase of the agricultural extension activities in many states. The present study, dealing with such work in West Virginia, was pursued in cooperation with the Division of Farm Population and Rural Life of the Bureau of Agricultural Economics, United States Department of Agriculture.

OBJECTIVES OF THE STUDY

The scope of this study includes:

1. An analysis of the structure, functions, and influences of 341 clubs in 39 counties. (Section II.)

2. A county study of farm boys of club age (10 to 18) who are not club members. (Section III.)

3. A case-study of a county in which 4-H work has made steady progress from its inception to the present time. (Section IV.)

4. A case-study of a county in which 4-H work once flourished, later greatly declined, and now is at a standstill. (Section V.)

5. A case-study of one club which is in some respects outstanding, in other respects average or below. (Section VI.)

6. An account of what 39 county supervisors of club work think are the chief problems, values, and obstacles in 4-H work. (Section VII.)

7. An analysis of the effects of club experience in the socializing of personal character. (Section VIII.)

8. Diary notes on a regional club leaders' conference. (Section IX.)

9. A specific statement about club work by a mother of six children, all of whom have been active in 4-H work. (Section X.)

10. Strong points and weak points of 4-H work. (Section XI.)

*Submitted for publication, July, 1929.

ACKNOWLEDGMENT

Appreciation and thanks for help in this study are due the following persons: W. M. Frye, Audra Gall, C. H. Hunter, Genevieve Porterfield, W. C. Schnopp, and Ocie Tune.

Methodology. The data for this study were gathered from 1926 to 1929 inclusive. The larger portion of the facts was obtained through personal interviews in the field. As a consequence of experimentation, original schedules were simplified, and the questions upon which information was sought were, in so far as possible, made to deal with objective data rather than with personal or group opinions. In Section II practically all of the information was obtained directly from club leaders or older boys or girls who were members of the particular club studied.

II. AN ANALYSIS OF THE STRUCTURE, FUNCTIONS, AND INFLUENCES OF 341 CLUBS IN 39 COUNTIES

In this section an analysis is made of significant sociological facts concerning a random sample of 341 of the 828 clubs in existence in the state during 1927-28. The median enrollment in these 341 clubs was 13, the average enrollment 15.5. The total 4-H enrollment in the state during 1927-28 was 13,328—an average of 16 per club.

Seventy-one percent of the clubs studied were in neighborhoods where general farming was the chief occupation. Four-H club work has had only slight success in mining communities for at least three reasons: (1) the 4-H projects, especially for boys, are designed primarily for practice on farms; (2) the mining population is so transient as to make it extremely difficult to retain even a moderately permanent club membership; (3) nearly all county supervisors of 4-H work consider their chief job to be with the farm boys and girls. Only two counties, Kanawha and Fayette, enrolled any considerable number of boys and girls from mining families.

In an endeavor to determine how many competing (or cooperating) groups of young people of club age were present in the respective club neighborhoods, it was found that substantially more than one-half of the clubs studied were in neighborhoods having no other organized group of young people.

Many Clubs Short-Lived

One of the greatest problems of 4-H work in West Virginia is that of keeping the clubs alive and active. Too many clubs lead a flickering existence and die out. It was found that 42.1 percent of all clubs studied were only in their first or second year, and 62.7 percent of the clubs were in neighborhoods that had not previously had a club. Undue effort on the part of county supervisors and local leaders is spent in organizing new clubs, and not enough time and effort are spent in carefully selecting the neighborhoods where clubs are to be started and then intelligently and persistently fostering these clubs through a series of years. About one in five of the clubs organized dies out. Adolescent groups change rapidly in personnel—a possible explanation of the circumstance.

The median age of the clubs studied was 2.7 years; the median

number of leaders, 1.1. On the average, the length of service for a club leader is between two and 2½ years.

The great majority of the 64 clubs having enrollments of more than 20 are found in villages or even larger towns. Four county seat towns, one with a population of 25,000, are found in this group. There is a tendency for the 4-H clubs in towns to suffer in vitality and interest because their members are active in other groups; also because the recreational or play element is likely to be emphasized more in these clubs than in those found in the open country.

Majority of Leaders Are Teachers

About three-fourths of the club leaders are school teachers. This situation has its advantages in that practically all club members are school pupils. Disadvantages are discussed in Section XI. It would be desirable to enlist the services as club leaders of a larger number of intelligent farm men and women, especially those who have had successful experience in 4-H work.

Nearly two-thirds of the club leaders have never had experience as rank and file club members. This is largely to be expected in view of the recency of the 4-H movement and the rather mature age of a large proportion of rural teachers in West Virginia, especially the men teachers.

Seventy percent of the clubs hold regular meetings once a month. Nearly all clubs have one or more special meetings during the year. These usually partake of the nature of picnics, wiener roasts, or hikes; some are intended to expedite project completions. The typical club meeting consists of three parts: opening service, consisting of club songs, other music, and devotions; business, with the chairman presiding, assisted by the adult leader; and recreation, games, and stunts.

The majority of the club meetings are held in the late afternoon, just before school is dismissed. In some cases ample time is allowed by the teacher and club leader for an unhurried and satisfactory meeting.

Seventy percent of the clubs receive adequate supervision as to frequency of visits by county workers. The ten percent visited by the county supervisor at every meeting are for the most part the new clubs which need help and the accessible clubs near the county seat.

In at least one county is club work so well organized and conveniently located that every club, weak or strong, near or distant, is regularly visited by either the county agent or home demonstration agent.

Not Enough Summer Supervision

A well-planned and well-executed activity for adolescent youth (like the 4-H program) is a vital formative influence in the development of boys or girls who actively participate in the program, yet

nearly one-third of the clubs are without their regular leader during the summer period, when project completion work and recreational activities should be at their height. In a relatively small number of cases special club agents are obtained for summer supervision. In Section XI this lack in a large number of clubs is pointed out as one of the weaknesses in the program. The situation is, however, not so untoward as might be expected in view of the fact that 249 of the club leaders were teachers and that only 100 of the leaders did not remain in their respective communities during the summer.

Making a liberal allowance for the clubs supervised by special agents during the summer, about 200 of the 945 clubs (1928-29) were without satisfactory summer supervision. Perhaps there is no single point in the whole range of club activities where a relatively small amount of money would go so far in raising standards of achievement as would the money necessary for at least a part-time 4-H club agent in every county of the state during the three summer months.

TABLE 1.—*Do 4-H club families have more good books in their homes than families in which there are no club members?*

	Yes	No	Unknown	Total
Number	286	33	22	341
Percentage	83.8	9.7	6.4	99.9

TABLE 2.—*Are the parents of club members recognized as community leaders more than are parents of non-club members?*

	Yes	No	Unknown	Total
Number	287	39	15	341
Percentage	84.1	11.1	4.4	99.6

FOUR-H FAMILIES ANALYZED

Tables 1 to 4 present a brief analysis of the intellectual, financial, and social (or community) status of 4-H club families. These tables show a high degree of correlation between club membership and the following four factors: more-than-average intellectual interests of the families from which club members come; above-the-average capacity of club members' families for community leadership; education of parents; and financial prosperity of parents.

The lowest degree of correlation in these four pairs of factors is found in the relation between club membership and education of parents. In 43 percent of the club neighborhoods there is no recognizable superiority of parents of club members over parents of non-members in the matter of formal education. Perhaps the chief explanation of this lies in the fact that until the last 15 or 20 years, opportunity for education in many parts of rural West Virginia has been rather limited.

In only four percent of the club neighborhoods was the attitude of parents found unanimously favorable to club work. On the other hand, practically no active opposition or hostility was noted any-

where. In the very few cases of actual opposition the reasons given were generally related to the parents' notion that club work was an unprofitable fad. The increasingly frequent demonstrations of the financial value of club work, especially in livestock and crop projects, are removing nearly all opposition to club work.

In only a few instances do club leaders consciously attempt to transform parental indifference into whole-hearted support. Nearly all clubs invite parents to their programs at least once a year. Other devices and methods could be used to accomplish this much-to-be-desired end of intelligent, general, and enthusiastic cooperation of the parents in support of the 4-H aims, ideals, and activities.

Movement Lacks Deserved Support

While considerable progress has been made in a few counties in obtaining some financial support and friendly sponsoring of 4-H work, a reasonable goal in this respect seems far in the future. From the viewpoint of value to the community, interest to themselves, and encouragement of developing boys and girls, there is no more promising and fruitful project for civic clubs and women's clubs than the intelligent fostering of 4-H work.

In some cases, such as the influence of improved methods taught in club work, the causative effect exerted upon parents by their children who are in club work is unmistakable and considerable; for there is no other ascertainable factor at work to produce the particular effect. For instance, definite improvements in sheep and dairy cattle breeding and in potato growing are traceable to the effects of 4-H work in certain sections of the state.

TABLE 3.—*Have parents of club members had more schooling than parents of non-club members?*

	Yes	No	Unknown	Total
Number	194	123	24	341
Percentage	56.9	36	7	99.9

TABLE 4.—*Are the families of 4-H club members more prosperous, financially, than families of boys and girls who do not belong to a 4-H club?*

	Yes	No	No difference	Unknown	Total
Number of clubs	256	17	54	14	341
Percentage of clubs ...	75	4.9	15.8	4.1	99.8

Beneficial Results Are Noticeable

An attempt was made to analyze the supposed effect in 4-H work of bringing about more intelligent and scientific farm practice and more adequate and satisfactory home and living conditions. One intelligent farm woman assured the field worker that she had learned many valuable methods in the canning of fruits and vegetables from her daughters, who had learned methods and technique through their 4-H canning projects.

If the data in Table 5 approximate accuracy, it seems that in about 85 percent of the clubs there has been more or less of this process to bring about better farming and farm homemaking. In 146 of the 341 clubs it is estimated that 25 percent or more of the 4-H members have thus definitely influenced their parents.

In 27.3 percent of the clubs studied there was evidence of some influence by club members upon their parents in the matter of keeping accounts of receipts and expenditures. This was true most frequently in potato and livestock projects.

TABLE 5.—*What percentage of 4-H club boys and girls in each club have influenced their parents to adopt better farming methods or get more home conveniences?*

	Percentage of boys and girls in each club who have exerted beneficial influence on parents								
	0	5 to 10 per-cent	15 to 20 per-cent	25 to 30 per-cent	35 to 40 per-cent	45 to 50 per-cent	Over 50 per-cent	Un-known	Total
Number of clubs	53	93	49	34	21	35	11	45	341
Percentage of all clubs	15.5	27.3	14.3	9.9	6.5	10.2	3.2	13.2	100.1

The connection between club membership and enrollment in certain public schools was found very close. Practically all club members were school pupils; each of the 47 clubs with fewer than 100 percent of their members enrolled as school pupils had very few such members. The usual number of boys or girls in any one club who were not attending school was one or two. In practically all cases the club members who were not pupils at the time the particular club was studied had recently been in school and were merely retaining their club membership a year or so until their fellows left school also.

On the other hand, 65 percent of the clubs enrolled fewer than one-half of the boys and girls of club age in their respective schools. Twenty-two percent of the clubs numbered fewer than one-fifth of the boys and girls eligible for membership. Parental indifference and cost of project materials were found the chief reasons why boys and girls did not join clubs. In a few isolated cases the club seemed to have been kept deliberately an exclusive group for children of certain families or of a select circle. One county agent mentioned this tendency among some of his clubs as a real problem.

Club Program Attracts the More Alert

In nine-tenths of all the clubs studied the leader seemed definitely convinced that the club program was more attractive to the brighter boys and girls. Possibly there should be an associate membership, without full privileges, for those boys and girls willing to do their part with projects and to cooperate in all club group activities, but for some reason unable to complete all the requirements for full-fledged membership. The move now in progress in West Virginia to have "standard" or "honor" clubs: i. e., to give special recognition

to clubs with almost a perfect score in project completion, is a step in the right direction. However, the real leadership training phase of 4-H work should not be diluted in order to allow weaklings to call themselves full-fledged 4-H members.

In 75 percent of the clubs there were evidences that non-club members did better school work because of the presence of a club in their school, even though they did not belong to the club themselves. The spirit of emulation and the effect of personal example are especially strong among adolescent boys and girls. This favorable effect of the presence of a club is perhaps one chief reason why progressive teachers, ambitious for their pupils, are willing to put forth the effort needed to supervise 4-H clubs in their respective schools.

In the matter of contributing toward higher standards of conduct, it seems that 4-H club influence scores even higher than in stimulating to better study. While 75 percent of the clubs showed the latter influence, 88 percent exerted the former.

Socializing Effects Are Evident

The connection between standards of personal and social conduct above the average on the one hand, and 4-H club experience on the other hand, seems definitely traceable. Both by precept and by example the 4-H program emphasizes clearly and strongly the value of wholesome moral character. It is very similar in this respect to the program of the Boy Scouts, Camp-Fire Girls, Girl Scouts, and Girl Reserves.

Nearly 75 percent of the clubs studied showed evidence that their club members remained in school longer than non-club members in the same school. No doubt this was only partly due to their club experience, because their greater native mentality, greater encouragement by parents, and greater financial prosperity of parents would all tend in this direction. The personal testimony of former club members, as shown in Section VIII, as well as the fact that a vital part of club experience is intellectual and educational, seem to make it certain that one factor in causing club members to continue their formal education longer than do non-club members, is the factor of ambition and stimulus toward the complete personal development which they had received from their 4-H club experience.

Practically all the clubs studied revealed distinct leadership qualities in play and recreation at school.

The training which club members receive in recreation at county and state camps and in their home club meetings is one of the most valuable contributions of the whole 4-H program to personal and community advancement. Inasmuch as most rural communities are decidedly lacking in adequate group recreation, it is especially fortunate that the 4-H clubs emphasize this aspect of their work. Typical games used by 4-H leaders are mentioned in Section IX.

Useful Reading Enhanced

The encouragement of good reading habits was found in 88.3 percent of the clubs. In the great majority of cases active interest was secured in completing the requirements of the regular pupils' reading-circle books, which compose a standard part of the extra-curricular activities of West Virginia elementary schools. In a considerable number of cases, however, the reading of club members went far beyond these requirements and included five to ten books of excellent fiction as well as biography, poetry, and history. Sometimes resourceful club leaders were found who occasionally would devote most of a regular meeting to reports and discussion of stories read by different members.

In a very large number of the farm homes good books are a luxury, and some of the brighter 4-H boys and girls are almost pathetically eager for good books to read. The owning and circulating among its members of even a few wholesome books is a real boon to many a club and to the homes from which the club members come.

Not many clubs have as yet been able to accumulate sufficient funds to undertake the responsibility of furnishing community library facilities. The fact that even 28.4 percent of the clubs studied are doing something in the way of providing books for the community speaks well for their ability at least to sense community needs in these respects.

The fact that 86.8 percent of the clubs exerted influences in the direction of new ideas and practices indicates that the ferment of at least friendly attitudes toward new and improved ways of doing things has been set to work by many of the clubs.

Wide Range of Social Activities

The 341 clubs exhibited a wide variety of social activities, ranging from hikes, picnics, box suppers, and socials to dramatics and money-making affairs.

Clubs with no members in county or state camps one year may have been represented in previous years. Thirty-five percent of the clubs in 1927 had no representative at any county camp. This circumstance was due chiefly to distance from the camp, pressure of farm work at home, financial inability, and, in a few cases, the fact that no county camp was held in their own county. On the other hand, nearly one-half of the clubs had three or more members at camp in that year.

The state camp at Jackson's Mill, while nearly in the geographic and population center of the state, is yet quite distant from the majority of the clubs in the state. Time, money, and an outstanding achievement record at home are necessary for the privilege of attending State Camp. One hundred eighteen of the 341 clubs were represented by at least one member at Jackson's Mill in 1927.

More than two-fifths of the clubs had honors or prizes to report for 1926-27. A wide variety of prizes and honors, many of them of a very substantial character, are available to West Virginia 4-H boys and girls. Cash prizes at state and county fairs, scholarships donated by railroad companies or farm women's clubs, and prizes by manufacturing concerns, are among the material rewards offered for real achievements in 4-H work.

"International" Honors Make Strong Appeal

For boys carrying livestock projects, the honor of participation in the work of a judging team at the International Livestock Exposition at Chicago is one of the most valued of the prizes.

Members in 68.3 percent of the clubs carried bank accounts. The practice of keeping careful records of costs and profits bears further fruit in helping to develop the habit of saving and of doing business in the modern way: i. e., through the banks. It is fair to assume that by their experience in buying materials, in keeping an account of amounts and values of feed used, and in buying cloth or eggs, the 4-H boys and girls who have bank accounts have found their club work a real factor in the development of thrift and of business-like attitudes and practices.

In 81.2 percent of the clubs some contribution toward the informal social life of the neighborhood was found. In 90 percent of the cases studied, 4-H members were found more active in the social and recreational life of the community than other young people of the same age. Community singing, dramatics, or demonstrations of some phase of club work often add zest and interest to the informal aspects of rural social life, and also make the adults more intelligent as to the nature and merits of club work. The more socially minded young people are drawn into the club work; and it is only reasonable to suppose that the 4-H experience of such young people definitely adds to their social efficiency by giving outlet and guidance to their potential sociability.

Nearly 90 percent of the club neighborhoods find that their 4-H young people are more active and helpful in church, Sunday School, and young people's societies than are other young people. This probably is partly a result of the emphasis upon the religious element in the 4-H program.

Interest in beautification projects, as demonstrated in nearly three-fourths of the clubs studied, does not always mean actual work along these lines, but at least it is a step in that direction. The 4-H influence here comes from the favorable attitude of all effective club leaders toward the practice of cleanliness and neatness, about the home, the school and church grounds, and, in a few cases, the community highways. It is not infrequent for a 4-H club to assume the responsibility of cleaning up the school yard, cutting weeds around the church building, or setting out trees and shrubbery on the school grounds. Also there is an increasing number of boys and girls who

carry home beautification projects, from which they receive intelligent guidance as to how to add beauty to their everyday surroundings.

Better Farming, Better Living Is Goal

Inasmuch as the 4-H program is maintained by the state and federal governments for the express purpose of promoting more intelligent agriculture and farm home-making, it would fall short of its purpose if it did not help the boys and girls who participate in its activities to put as much as possible of their education and knowledge into daily practice. This reasonable goal of 4-H work is, to a considerable extent, actually achieved.

Large community enterprises in rural communities are few. That is one reason why only two percent of the clubs have achievements of this kind to their credit. Only in rare instances do club members have the age, experience, and leadership capacity to function in a prominent way among the adult, tax-paying members of the community. One notable instance, however, is on record where the 4-H club members were the chief factor in the voting of bonds for a new high school.

The improvements in community life mentioned in the cases of 249 of the 341 clubs ranged from material improvements such as a new high school building to intangible factors such as better relationships between adults and young people or between town and country people. Most of the 92 club neighborhoods where no such improvement was in evidence were those neighborhoods in which club work was of very recent origin.

III. A COUNTY STUDY OF BOYS OF CLUB AGE WHO ARE NOT CLUB MEMBERS*

(A Study of 557 Boys in One County)

Monongalia County, a representative farming and mining county in northcentral West Virginia, was selected. With the exception of the city of Morgantown, practically all the people of the county live under rural or semi-rural conditions. Three small incorporated villages, but none of the schools of the city of Morgantown, are included in this study.

The county is probably above the average in the development of 4-H club work. The farm people have had the advantage of the leadership of a competent county agent and home demonstration agent for several years, and the State University is situated at Morgantown.

The fact that Morgan district, in which Morgantown is located, has 12 4-H clubs in its 22 rural schools, and Clinton district, one of the isolated agricultural sections, has only three clubs in its 22 rural schools, makes it apparent that proximity to the county seat and the

presence of a hard-road system are significant factors in determining the extent of 4-H club development. This situation prevails quite generally over the state.

RELATION OF CLUBS TO SIZE OF SCHOOLS

The 147 country schools vary in size from one to three or more rooms. The 43 schools with two rooms or more are found mostly in neighborhoods where the population is partly mining and partly agricultural. The 104 one-room country schools had 18 clubs, and 82 percent of the distinctly farming neighborhoods of the county were without any 4-H program.

Of the 43 schools having two or more rooms, 17 schools, or 40 percent, had 4-H clubs, as compared with 18 percent of the 104 one-room schools. Nearly all the larger schools are found on or near hard roads.

The three magisterial districts lying nearest Morgantown, the county seat, and also having the best hard road system, averaged one club to three schools. The school enrollment in these three districts averaged 29. The four magisterial districts lying farthest from Morgantown, having the poorest roads and an average school enrollment of 20, averaged one club to six schools.

While the 4-H program is valuable in the larger schools it is still more valuable and more urgently needed in the one-room school neighborhoods. These more isolated neighborhoods usually have very slightly developed group activities of any worth-while kind.

Small Schools a Handicap

Small school enrollments are handicaps to effective 4-H club organization. While it is possible to have a club of five members, eight, ten, or 12 members are necessary to a vitally functioning group. Many one-room schools do not have enough boys and girls of club age (10-18) to encourage the organization of a club. A school enrollment of 20 or more is usually necessary to include enough older boys and girls to make a worth-while club.

The average school enrollment in the four magisterial districts of the county having the most purely farming population was 20, with a considerable number lower than 20. In the other three districts the average enrollment was 29. Small enrollment in a large number of the schools in distinctly farming neighborhoods is an additional factor tending to determine the extent and quality of club work in this county.

---

*Dr. C. B. Smith, chief of the office of cooperative extension work in the United States Department of Agriculture, made the following suggestion in regard to this study of 4-H work in West Virginia: "That objectives include:

"(1) An analysis in one or more counties of the number of rural boys between the ages of 10 and 18 not in any school and not in club work, with their respective ages.

"(2) The present occupation of such boys; or how they are spending their time.

"(3) The reasons why such boys are not in school."

Personal interviews with teachers, former schoolmates, and brothers and sisters of the boys who were the object of the study, were employed.

When one takes into account the combined facts that, in this county, a very high percentage of the small one-room schools are in the more isolated and inaccessible neighborhoods, distant from the county seat and away from hard roads, one can readily understand that this combination of unfavorable conditions creates a limiting circle of cause and effect and operates to keep the 4-H club program at a minimum where its services are most needed.

An illustration of how rural migration also sometimes affects 4-H club work is found in the following note of the field worker concerning a certain school visited: "There was a 4-H club here, but it ceased to exist when the chief families moved away two years ago." In the farm neighborhood the moving away of a few families is often fatal to the neighborhood organizations.

None of the six schools for negro children in the county had a 4-H club.

Age of 15 Often is Turning Point

Most boys left school at about 15 years of age and beyond. The rather sharp increase in the number of those dropping out at 16 as compared with age 15 is explained partly by the fact that the West Virginia law allows boys to work in coal mines at 16. Twenty-four percent of the 557 boys included in this analysis were actually working in coal mines when the data were obtained. The 4-H program is not designed especially for coal miners and naturally the boys who left school to work in the mines would be inclined to drop their 4-H club membership at the same time.

TABLE 6.—*Chief reasons why the boys dropped out of school*

Chief reason given	Number of boys for whom this reason was given	Percentage
Indifference	172	30.9
Help needed to support family	140	25.1
Had completed eighth grade in school	98	17.6
Wanted to go to work	66	11.8
Parents not interested in having the boy stay in school	44	7.9
Prolonged sickness	20	3.6
Inability to do school work	7	1.3
Conduct problems	5	.9
Too great a distance from school	5	.9
Total	557	100.0

The two leading causes given for dropping out of school, as shown in Table 6, were lack of interest in school work on the part of the boy, and economic necessity. As to the economic cause, one should probably not interpret it to mean that 140 boys were compelled to drop out of school to prevent actual suffering in their families. It rather means, in most cases, that the standard of living of farm families in this county is slowly rising and that the older boys of the larger families desired to help maintain this rising stand-

ard when they reached the point where they could make tangible contributions to the family income.

Ninety percent or more of the boys of 4-H club age who had left school were not enrolled in 4-H club work. It was found that 155 lived near enough to a club to make membership possible, but only 16 of these availed themselves of the opportunity.

One-fifth of Boys Farming

About 80 percent of the fathers of the 557 boys earn their living entirely or chiefly by farming. Table 7 shows that only 111 of the boys, or 20 percent, were following that occupation.

TABLE 7.—*Present occupations of the boys*

Occupation	Number	Percentage
Miner	133	23.9
Farmer	111	19.9
Loafing	80	14.3
Glass worker	74	13.3
Day laborer	41	7.3
Clerk in store	13	2.3
Dairyman	11	2.0
Working in stone quarry	9	1.6
Teamster	9	1.6
Truck driver	9	1.6
Lumberman	7	1.1
Mechanic	6	1.0
Tin plate worker	4	0.7
Junk collector	3	0.5
Porter in hotel	3	0.5
Working in shoe shop	2	0.4
Selling papers	2	0.4
Working in restaurant	2	0.4
Making and selling moonshine whiskey	2	0.4
Working in pool room	1	0.2
Working in bakery	1	0.2
Unknown	34	6.0
Total	557	99.6

Only one-fourth of the boys in farm families were following their fathers' occupation. No doubt this fact is a large causal factor in the low percentage of older boys out of school who are doing 4-H club work. The whole 4-H program is organized primarily for boys and girls whose families make their living in agriculture. When an older boy leaves that occupation his chief incentive to 4-H club work is gone.

In the more purely agricultural counties the percentage of boys and girls who stay in club work for a short time after they leave school is higher than it is in Monongalia. In the large number of counties, however, where the occupations of farming and mining are much intermingled, very much the same conditions prevail as in Monongalia County.

IV. A CASE-STUDY OF A COUNTY IN WHICH 4-H WORK HAS GONE STEADILY FORWARD

Four-H club work in Barbour County had its origin in corn clubs. The first of these was organized in 1911 with a membership of five boys. In 1912 the clubs were conducted by the teachers under the direction of the county superintendent of schools. The total membership of these clubs was 300; of these, 47 percent exhibited at the county fair. These clubs were intended to give the farm boys and girls something of their own and to give them recognition as owners and operators. In 1913 the name of these clubs was changed from "West Virginia Boys' Corn Club" to "West Virginia Boys' and Girls' Agriculture Club."

Local Fairs Popular at Start

During the early years of club work in the county, communities held local fairs in which the boys and girls held the most prominent part. Local citizens contributed money and suitable articles for prizes and thus stimulated and maintained the interest of the boys and girls. Valley District was the only one to continue this practice for any length of time. One member received a trip to Morgantown as a prize for his Reid's yellow dent corn, which yielded 33 bushels per acre.

With the help of its first county agent, Barbour County in 1915 ranked fifth in the state in club membership, with an enrollment of 204 in about eight clubs. Six boys received prizes which entitled them to a trip to the Prize Winners' Course at Morgantown in January, 1916. All were from the Kerr Club. Four of them received prizes on exhibits or on judging.

In 1917 more than 100 boys and girls in six clubs carried on pig, corn, potato, or poultry projects.

The first girls' club in the county associated with the Agricultural Extension Division of the State University was organized at Mountain View in 1918 with cold-pack canning and sewing projects. The club was discontinued because of lack of local and county leadership.

Several of the clubs survived the War. Emphasis now was put on organization, and the social and religious phases were stressed for the first time,—a feature which distinguishes 4-H clubs from other agricultural clubs. Eight or ten clubs were active in 1919.

First County Camp in 1919

The first county camp was held in 1919 at Audra. Four local leaders, three camp instructors, and 20 boys and girls attended. For the first time the 4-H idea was emphasized, and from that time it has developed steadily.

A few more clubs were organized in 1920. The county agent endeavored to strengthen the clubs by urging old members to continue, developing club spirit, making home visits, encouraging more complete organization, and emphasizing the social hour.

The second county camp was held in 1920. The first county 4-H organization was formed at this camp. About 30 club members attended, and six directors and instructors. The camp did much to strengthen club work in the county.

This was the first year for local leaders to receive financial reward. Four were employed. In November, 1920, the first coupons of credit were offered to teachers who would sponsor club work.

Lack of appreciation of the value of the work on the part of farmers, and a feeling on the part of certain business men that farmers' organizations would hinder their business, proved a deterrent to effective club work from the beginning. The county was without a county agent for six months in 1921. As a result no camp was held, and club work declined somewhat.

Many New Clubs in 1922

In 1922 many new clubs were organized. Three women as local leaders helped with the girls' work, and three men assisted with the boys' work. Sewing and canning projects were introduced this year. Thirty-five members attended camp and two won their 4-H pins.

In 1923 several state leaders visited the county. Two women and one man were employed to work on part time during the summer. There were 21 clubs with a membership of more than 300, and during the summer the work was carried to new communities.

Many of the clubs had efficient local leaders, as illustrated in the Silent Grove Club. In 1922 regular, well-planned programs were given. In 1923, when there was no local leader, meetings became irregular and several members dropped out.

In 1923 the camp site was changed from Audra to a more centrally located place near Volga. A banker at Philippi, the county seat, gave land for a camp site. Men of the community dug a well and put the grounds in condition for camp. There were nine camp instructors, four local leaders, and 60 regular campers. Three received their 4-H pins.

In the fall of this year a home demonstration agent was employed.

Kerr's History Given

Kerr club is one of the oldest and most outstanding clubs in Barbour County and in the state. Starting as a corn club and never boasting a large membership, it has had an unusual influence upon the individual club members and the community. Although it was the first corn club to be organized in the county, it has a steady record of achievement for every year down to the present. The terrain is rough and the soil is poor. The 4-H club and the one-room school, which is used for headquarters for 4-H activities, are the only vital community institutions.

Besides fostering excellent project work and winning many prizes, Kerr Club members have promoted school entertainments, debating, literary programs, and picnics which have become genuine

community affairs. One family has contributed in an unusually effective manner to the maintenance of high standards of club work, and the club has, in turn, meant much to the social development of these men and women personally. They are now teachers and leading citizens of the community; two are succeeding in business in out-of-state cities, and two younger ones are still in club work.

The services of this 4-H club to the community have been the more valuable and needed because of the rather extreme isolation of the neighborhood, five miles from a passable road and 12 miles from the nearest town.

Mountain View Club was another small but successful club. At first there were only six members, and their record for 1915 shows an attendance of 100 percent at the meetings. One member, now in partnership with his father and one of the outstanding farmers in the county, attributes much of his success to the training received in 4-H club work. Others hold responsible positions in various occupations.

Genuine Support from Business Men

The period from 1923 to 1928 was one of steady growth and constant achievement in Barbour County. The 4-H program became familiar to all citizens of the county. Perhaps the greatest single reason is seen in the impetus given to more successful potato growing and sheep raising—the chief sources of cash income. The two Kiwanis clubs in Philippi and Belington, as well as the bankers and merchants, have given cordial and substantial support to the 4-H work, both because of their interest in the boys and girls and because 4-H work has contributed directly toward better business. Assistance has been in the form of loaning money for purchase of lambs and seed potatoes, in taking a friendly interest in the boys and girls and in their projects, and in giving all who completed their potato projects a recognition dinner at the close of the harvest.

The business and professional men of the county also give encouragement to the 4-H work by visiting the county camp, making talks to the campers, and by speaking a good word for the 4-H program in their daily contacts.

RESULTS AFTER 17 YEARS

Some of the more significant and valuable results of 17 years of continuous 4-H club work in Barbour County may be summarized as follows:

1. A substantial contribution to more scientific and more profitable agriculture, especially in the fields of potato production and sheep raising.

2. A large contribution to a more vital recreational life of the teen-age young people. This has been accomplished largely through the training in group games, stunts, and group singing fostered by the county camps and by the more resourceful club groups in their respective local communities.

3. The bringing about of a more friendly and mutually helpful relationship between the farm people of the county and the business and professional people of the two leading towns of the county. The good will thus engendered and the increase in actual money profits obtained as a result of this helpful cooperation between town and country are plainly noticeable.

4. The all-around personal development that has been brought about in the lives and characters of a large number of boys and girls who have been active in 4-H work. This personal development includes ability to achieve substantial results in the technical and business aspects of agriculture, creation of interests and ambitions for high school and college education, and ability to serve the community as effective leaders. One specific evidence of this developing effect of club work is found in the large number of state prize winners coming from this county and the fact that one small club (Kerr) won so many prizes for two or three years that it was temporarily forbidden to compete for prizes.

An interesting example of how certain 4-H projects may be used to develop community interest and pride is found in the community beautification project performed by the 4-H club of Philippi, the county seat and largest town in the county. This rather large club, of more than 30 members, took as its group project the beautifying and improving of the school grounds. Through the planting and the setting out of shrubbery, the appearance of the school grounds, in which all the community is interested, was greatly transformed. No doubt the creation of a more vital pride and interest in their community by the team work on the part of the boys and girls who carried the project through was the most valuable result of this enterprise.

REASONS FOR SUCCESS

In summarizing some of the more important reasons why 4-H club work has gone steadily forward in Barbour County, the following factors should be noted:

1. More competent and more permanent county leadership than most of the West Virginia counties have had. This is especially true in the 1923-28 period, during which there was no change in personnel of either the county agricultural agent or the county home demonstration agent.

2. The more-than-average interest of the representative and influential adult people of the county in the 4-H program.

3. In recent years the building of a well-coordinated system of county and state roads in Barbour County has greatly increased the ease and efficiency of county supervision.

4. It has been partly accidental that a considerable number of energetic and intelligent families have been actively connected with club work. These have made notable contributions to club work through their perseverance, intelligence, industry, and loyalty to club ideals and principles.

V. A CASE-STUDY OF A COUNTY WHERE 4-H WORK HAS DECLINED

Monroe County, situated in the southeastern part of the state on the edge of the Blue Ridge Mountains, is of rolling topography. Union, the county seat, is the largest town, with a population of about 1000. General farming and beef cattle raising are the chief occupations.

There are four high schools: Union, Peterstown, Gap Mills, and Greenville. The average attendance at each is about 90. Several graded schools and many one-room schools are to be found in the county.

Bad roads have been the chief drawback to social betterment in the county, but with the coming of good roads social conditions are improving.

Practically no foreigners live in the county, but there are several settlements of negroes. A considerable number of the characteristic mountain people may be found.

GROWTH OF 4-H CLUB WORK

Monroe was one of the first counties in West Virginia to take an interest in 4-H club work. Corn clubs were organized in 1912 or 1913—forerunners of 4-H club project work.

In 1915 the first county camp was held. Monroe was thus the second county in the state to hold a county camp. The Extension Division of the College of Agriculture sponsored a number of contests, and in this county five members entered the acre corn contest, 45 the 200-hill corn contest, one the poultry, one the pig, and one the potato contest.

The county's first agricultural agent began work in July, 1916. At this time 4-H club work was establishing itself in the state as well as in the county. Forty-six boys and girls attended the county camp in that year. Salt Sulphur Springs, an old but attractive summer resort situated four miles from Union and almost in the center of the county, was the site for this and later camps.

There were games, story telling, nature classes, study of Bible characters, first aid, Indian lore, stunt nights, and campfire. In spite of the constructive character of the meetings, some of the people in time withdrew their support and their children from 4-H work, fearing too much recreation.

The camp of 1917 was called a "Boys' Institute", although girls also attended. About 75 campers attended the five-day event.

There were three girls' clubs in the county in 1917. The projects were limited to a few activities such as raising chickens and pigs. Canning and sewing were introduced. Up to this time most of the clubs had been organized in the eastern part of the county and around Union.

Many new clubs were organized in 1918. Almost every school

had a 4-H club, with the teacher as volunteer leader. The county camp attendance for 1918 was 166. Several of the state leaders assisted. A 4-H fair was held at Salt Sulphur Springs.

Two Club Agents Employed in 1919

During 1918-19 between 20 and 30 4-H clubs existed in the county, with a total membership of about 650. In 1919 both a girls' and a boys' club agent were employed.

In the summer of 1918 six girls in the Sinks Grove Community, calling themselves "The Big Six", held a practice meeting prior to county camp. At camp they asked to be placed in a single tribe. This request was granted on the condition that they would allow a first-year girl to be chief (The Big Six had all been in club work five years). The other tribes had experienced chiefs, but this one worked hard, finishing camp with more points than any other tribe.

The mutual friendship of the girls in this unique club has proved to be one of its outstanding features. Coming in contact with experienced leaders and working with other groups also has brought its benefits. Their work attracted attention to the county, at that time one of the foremost in 4-H club work in the state.

Good Attendance at County Camp

The attendance at the county camp in 1919 was about 100. Six state leaders assisted with the camp. Each club had its own exhibit.

Five club agents were employed in 1920. During 1920 and 1921, 12 local paid leaders helped with the work. There were ten representatives of the county.

The 1920 county camp had an attendance of 115, while that of 1921 dropped to 73—a decrease due primarily to lack of leadership, for the county agent had left the county in February, 1920.

In September, 1921, a home demonstration agent was appointed. In the spring of 1922 district club days were held with the assistance of the agent and the club leaders.

Practically all of the clubs organized in 1919 were still in operation in 1922. In both this year and the next, two camps were held each year: a senior camp for club members 14 years and older, and a junior camp for those from 10 to 14 years.

In the spring of 1923 the home demonstration agent was instrumental in arranging public school days as well as the county public school day. These occasions consisted of literary, dramatic, and athletic events and proved strong drawing cards for the adult people of the neighborhood.

Fall leaders' meetings were held in 1922 and 1923 at "The Salt".

Interest Waned with Loss of Leader

There were 20 organized and active clubs in 1923, with a total enrollment of 350 members. In 1924 this had dropped to ten clubs with an enrollment of 197 and an attendance of 43 at the county camp. The slump was due largely to lack of leadership, for the home demonstration agent left in 1923. In 1924 a county agent was employed who did not stress 4-H work as his predecessors had done. The camp of 1924 was the last one held in the county, for the buildings at The Salt were now old and unsafe. Those who wished to attend camp now went to the Summers County camp at Barger's Springs.

From 1921 to 1925 many boys and girls from Monroe County attended the camps and volunteers' conferences at the Jackson's Mill state camp. Many demonstration and judging teams were sent to district and state fairs, where they won many prizes.

In 1924 a campaign was begun for funds for a Monroe County cottage at Jackson's Mill. The cottage was completed in 1927 at a cost of $3000, and the necessary funds were raised by 1928.

In 1925 sixteen boys and girls from Monroe County attended the 4-H camp in Summers County. Interest in camp work was at low ebb. In 1926, 152 children were enrolled in 4-H clubs. Thirty volunteer leaders assisted.

During 1927 there were only seven clubs with an enrollment of 82, in spite of the fact that a county agent was employed. One of the clubs organized a Christian Endeavor Society; another undertook an anti-fly campaign; another took care of the school grounds during the summer months. The girls of one club completed a piece of sewing each month so that their sewing projects were completed when school closed. Twenty-one members attended camp in Summers County. Twenty-eight completed their projects in time to exhibit them at the Greenbrier Valley Fair. Two clubs made club exhibits. The Waiteville Club demonstrated with a club night program at the close of the club year and invited adults. This entertainment revived considerably the sentiment in favor of 4-H work.

The decline of club work in Monroe County dates from the time paid leadership was discontinued. By 1929 the county had neither county agent, home demonstration agent, nor paid club leader.

FACTORS WHICH CAUSED 4-H WORK TO SLUMP

1. The county home demonstration agent who first built up 4-H work in the county was an enthusiastic leader herself, but failed to develop leadership in others.

2. The district leaders who were paid relatively small amounts for their work were important cogs in the wheel of good club work. When their pay was stopped most of them felt they could no longer afford to supervise club work.

3. Some dissatisfaction was felt because the financing of the county cottage at the state camp was ardently pursued, perhaps ahead of some of the local work.

4. The county court became more interested in building hard roads than in helping finance 4-H club supervision.

5. Rather frequent shifts in county agents. The last agent was more interested in building up young people's religious societies than in fostering 4-H club work.

VI. A CASE-STUDY OF ONE 4-H CLUB*

This chapter is a chronological case-study of an influential 4-H club in northern West Virginia. With a longer history than most clubs, this club was selected because of its relatively long process of evolution and because it illustrates several significant conditions which make for success or failure in 4-H clubs. Among these conditions of success are: adequate, intelligent, responsible leadership; a homogeneous and stable population type in the club community; the sensitiveness of 4-H groups to friendly support, or lack of such, from their elders; and the possibilities of 4-H clubs as vital factors in community improvement.

1916: the Progressive Young Farmers' Club was organized in April with 21 charter members; 2 meetings held, but club was forced to discontinue for 1 year, and leader resigned because of parental opposition.

1918: club reorganized with 12 members and a new leader; projects carried through the summer; club discontinued for one year.

1920-21: new leader took charge; nearly all members completed projects; good meetings every two weeks; sponsored a community meeting which aroused interest of parents; 14 members attended county 4-H camp.

1921-22: club had 40 members and 2 leaders; nearly all members completed projects and attended fair; a social, with money-making features, held every month during summer; club presented a play (the first ever presented in one community) in two communities and cleared $50, to send winning members to Prize Winners' Course at Morgantown; 15 attended county camp and 3 won the 4-H emblem; club sponsored successful community meeting; club party given at end of year; club began to attract attention even outside county.

1922-23: community meeting sponsored by club attended by 300 people; another play given; attitude of parents and patrons had changed from one of hostility to one of approval; club sent 2 representatives to 2 of state camps.

1923-24: a "get acquainted" community social held at beginning of year; 8 new members added, making total of 37; 75 percent of members completed projects; club exhibit won first prize at county

*The information contained in this section was gathered by C. H. Hunter, a senior in the College of Agriculture of West Virginia University and a resident of the neighborhood in which the club is situated. (Stewartstown Club, Monongalia County.)

fair; 1 girl took grand championship, and numerous other prizes were won by members; 8 attended county camp; 1 member earned 4-H emblem; 3 formed a stock-judging team and represented county in state contest, winning first place there and twelfth place at Chicago in International Non-collegiate Livestock Judging Contest; at state fair, club leader was awarded $100 scholarship given by State Bankers' Association for being West Virginia's best all-around club member for that year; members took part in school programs and entertainments; cleared $24 at social; took active part in clean-up campaign; club pledged and paid $50 toward community building; Community Council arranged stunt night, at which club won second prize; a Hallowe'en party and a "wind-up" party held in two of the homes.

1924-25: slump in coal business in the two villages which had furnished many club members affected club, for families moved in and out and members did not remain long enough to complete projects; only 9 members completed theirs; no county or community fair held, but county agent judged projects; 1 boy attended State Boys' Camp; 2 members attended Volunteer Club Leaders' Camp; 1 of these elected to All-Star group; 9 members attended county camp; 1 boy earned 4-H emblem; several chosen as outstanding in fourfold development; 2 socials and a festival held; club aided toward completion of community building.

1925-26: club had 11 old and 5 new members; 10 of these completed projects and exhibited at community fair; 2 members attended Volunteer Leaders' Camp at Jackson's Mill; 11 went to county camp; of these, four chosen as outstanding; 3 won 4-H honors; fat pig raised by one of members won first prize in state contest; more than usual number of meetings held in order to keep up interest; at two meetings vesper services held, followed by camp fire; club pledged $300 to fund for county cottage at Jackson's Mill; illustrated lecture, festival, food sale, amateur circus, and play were employed to help liquidate amount of pledge.

1926-27: 14 old members and 6 new ones enrolled—about 60 percent of those eligible for club work; 2 regular meetings held each month; sewing, pigs, corn, potatoes, and poultry projects carried on; 3 of All-Star members attended All-Star Camp and Volunteer Leaders' Camp; club leader was editor of camp paper; 1 girl sent to girls' state camp; 11 members went to county camp; 1 member chosen as outstanding in fourfold development; 3 of older members served as volunteer instructors.

1927-28: leader, who had ably directed the club since 1923, was now sophomore in State University and unable to continue work with club; club slumped and nearly died; 4 boys and 6 girls enrolled (3 moved away); 1 completed his project and exhibited it; meetings scheduled every month, but chairman, high school student, often was unable to attend and called off many meetings; 1 member attended county camp.

1928-29: small enrollment, made up of first and second-year members; gave large basket of food and clothing to Salvation Army at Christmas time.

Of 40 charter and early club members (1916-20), 21 are still living in the same community, but not all of these are farming. Three of the 40 have died.

VII. WHAT THIRTY-NINE COUNTY SUPERVISORS OF CLUB WORK CONSIDER SOME OF ITS GREATEST VALUES AND PROBLEMS*

Questionnaires were sent to 40 county agents, 20 home demonstrations agents, and six special club agents. Thirty-nine replies were received from the 66 questionnaires.

Out of 25 values mentioned, the following head the list: training in leadership, initiative, selfcontrol, good workmanship, friendship and education from contact with others, and personal development.

Twenty-three community or neighborhood values were listed. Those associated with community spirit, cooperation, and training for community leadership ranked highest, with the value of improving community conditions in farming and home-making a close second.

Competent local leadership was regarded as the most important factor in club work direction. The other two factors placed distinctly in the lead were favorable attitudes of parents and teachers and a vital interest on the part of the boys and girls themselves.

Lack of adequate local leadership, scarcity of vitally favorable parental attitudes, and poor roads were listed among the chief hindering factors that prevent both greater quantity and better quality of club work.

More than two-thirds of the county leaders were of the opinion that flexibility of standards for the admission of new club members is justified, but they also averred that the development of the potential leaders in the club group and community should always be kept in mind.

Sixteen reasons were given why boys and girls drop out of club work. Parental indifference, lack of ambition and of persistence on the part of club members, and inadequate leadership loomed up as the chief explanations of the unfortunately rapid turnover in club membership. If the estimate is correct that the average period of individual club membership is about one year, then herein lies one of the great unsolved problems of more effective club work. The large army of joiners and quitters get little or no benefit from their club experience; rather, they often create real problems for the leader and the more faithful and persistent members.

*The information upon which Section VII is based was obtained entirely by correspondence.

VIII. WHAT SEVENTY MEN AND WOMEN SAY THEIR CLUB EXPERIENCE DID FOR THEM*

This part of the study is an attempt to analyze the effects of fairly extensive 4-H experience as they reveal themselves in the present attitudes, character traits, and social behavior of 34 men and 36 women. Fifty-two of these had three or more years' experience as club members; they were more or less outstanding members, for the average period of club membership in the state is about one year.

Fifty-six had graduated from high school, 18 had graduated from college, and 22 were attending college at the time of inquiry.

Practically all these 70 men and women were under 30 years of age. More than one-half were under 25.

One-third Began 4-H Work at Advantageous Age

Only 23 began their club work at the most favorable ages—10, 11, and 12. More than one-half began their club experience at older ages. No doubt the rapid turnover in club membership has been due partly to the fact that a large proportion of boys and girls join at an age when they have only one or two years of most active club interest ahead of them. Ages 12 to 15 are the period of adolescence when club life makes its strongest appeal to nearly all boys and girls.

The median number of years spent in club work by these 70 was nearly 3½. This was a long enough contact with club activities to make it fairly certain that their latest interests, attitudes, and activities were, to a considerable extent, due to their 4-H work and relationships.

The median number of projects completed was 3.1. The number of completions averages almost exactly one for each year for each boy or girl under consideration. This means that these outstanding boys and girls did twice as well as the rank and file of club membership, since only about 50 percent of the projects enrolled for were actually completed (1927-28).

Returns Re-invested in Four Directions

Expenditures of money made on 4-H projects seem to have been mostly for education, travel, clothes, and savings. These four items reflect fairly well the most urgent needs or desires of most farm boys and girls, whether or not they belong to 4-H clubs.

Nearly one-half of the 70 belonged to relatively small clubs (under 16 persons). The fact that 15 belonged to very small clubs (5 to 10 members) shows that a group need not be large to furnish an environment which will help produce outstanding individuals. Probably 12 to 15 members make the most desirable size of club for the average leader and the usual circumstances found in rural neigh-

*This study was undertaken upon the suggestion of Dr. C. J. Galpin, economist in charge of the Division of Farm Population and Rural Life, Bureau of Agricultural Economics, U. S. Department of Agriculture.

borhoods. Smaller groups are distinctly limited in what they can undertake as group projects or activities.

The one or more club offices held by 46 of the 70 inevitably contributed to their ability as group leaders and added to their capacity for taking responsibility.

Inasmuch as club leaders, supervisors, and rank and file members are all agreed that attendance at county camps is one of the most vitalizing and socializing factors in the whole 4-H program, it is unfortunate that one-third of these men and women never had or used the opportunity to attend even one county camp. (In the earlier days county camps were relatively few.)

The state 4-H camp at Jackson's Mill is of even more recent origin than the county camps. Fifty never attended the state camp.

The three honors most desired and cherished by the 70 boys and girls were the 4-H pin (an emblem of high achievement in the four-fold life—head, hand, health, and heart); the trip to Morgantown (where the State University is situated and where the early prize-winners' courses were held, before the state camp was developed); and All-Star membership. The All-Stars are regarded as the most active and interested group of men and women in the state in the promotion of the 4-H program.

Honesty, Industry Rank Highest in Calendar of Useful Traits

These 70 must have received quite definite impressions of their club leaders to be able to mention 21 traits a total of 452 times, six or eight years after their club experience had come to an end. Honesty and industry ranked highest, with dependableness, patience, and good judgment next in importance.

The percentage of those who are affiliated with the church and active in some phase of its work is considerably higher than the percentage of such in the general population. Because of the fact that the West Virginia 4-H program places considerable emphasis on the vesper services and other religious or spiritual elements of its program, it seems fair to conclude that a part of the reason for this greater showing lies in the influence of club work.

Only 25 Now in Agricultural Occupations

Only 25 are now farmers, farm home makers, county agents, or home demonstration agents. Possibly ten of the 22 who are now students may later return to the farm. About one-half of the more capable 4-H boys and girls, it seems, are leaving the country for town and city life and work.

Not only are farm taxpayers educating many boys and girls in the schools who later became citizens of towns and cities, but the same process goes on in the field of 4-H work. In so far, however, as 4-H work is supported by federal and even state funds, much of its financial support comes from town and city taxpayers.

Forty-three asserted that certain benefits had been derived from their 4-H experience which had been of use to them in their present occupation.

The fact that 33 of the 70 declared that their 4-H experience had not influenced their choice of a permanent occupation may mean that more attention should be given by club leaders to the problems of vocational guidance. These leaders are in a strategic position to give valuable aid if they are sufficiently trained in adolescent psychology and sufficiently informed concerning occupational trends and requirements.

Contact with leaders and 4-H camps decidedly head the list of the phases of club work which have most influenced these 70 men and women. Self-reliance and ambition are distinctly in the forefront of personal or character traits which they believe were developed through their 4-H experience.

Influence Cited by Parents

Many parents commented, with pathetic emphasis, on how much the 4-H club had done for their boy or girl in helping him or her to "stand on his feet and express his own ideas."

The simple but essential health principles emphasized in the 4-H program had noticeable and favorable effects on 60 percent of these men and women. The 4-H program, when participated in with good cheer and heartiness, is bound to make a real contribution toward better conditions in rural health.

Club members are naturally most affected (in the matter of particular skills acquired) by the type of project carried. For example, the sewing project was listed as most helpful in the acquiring of skill. Farm people are in special need of more technical skill and business-like practices, and 4-H work makes a definite contribution toward such. It also helps to develop special technical skills.

In about 85 percent of the 70 cases definite contributions to social development were noted. Nearly every element of club activities has at least some social aspect; and some of the features of the work are included especially for their socializing effect. It seems strange that even 15 percent of these men and women could testify that their 4-H experience had had no such effect.

The effectiveness of the moral and spiritual phase of 4-H activities is evidenced by the fact that nearly 80 percent of the 70 attribute a definite part of their moral and spiritual development to their 4-H experience.

Need for Trained Leaders Emphasized

It is significant that the greatest single need mentioned for the improvement and extension of 4-H activities is the need for a greater number of trained and selected leaders who are able and willing to devote themselves wholeheartedly to self-imposed tasks.

Some further evidence of the nature of the social behavior of these 70 selected men and women is found in the following facts:

Twenty-nine are members of a civic, community, or fraternal club. Thirty-one have held one or more offices in such organizations. In these respects the proportion of group activity and leadership is considerably above the proportion found in the rank and file of farm men and women or even of those in town or city, to which about half of these former club members have gone. Twenty-seven are married and six of these married former club members.

IX. DIARY NOTES ON A REGIONAL CLUB LEADERS' CONFERENCE*

The regional conference (May 16-18, 1929) was in charge of the district county agent and the district home demonstration agent. About ten of the most competent county agents, home demonstration agents, and local club leaders also had charge of certain sections of the three-day program.

The conference was made up of 45 local club leaders, picked from nine counties, and ten persons of the directing group. This was one of seven district conferences held in the state in the spring of 1929. It is the aim of the Agricultural Extension Division to make these sessions annual affairs.

The following abbreviated narrative of the conference is taken from diary notes.

FIRST DAY

Afternoon and evening spent in getting room assignments and in informal recreation. Delegates housed in inexpensive but comfortable and attractive summer hotel on banks of beautiful Greenbrier River. Dart baseball most popular lawn game. Much group chatting and visiting. Supper served at 5:30, followed by more lawn play until sunset, when all gathered in dining room for well-planned series of songs and stunts. A grand march, dancing, humorous reading, group singing, serving of punch. Evening closed with 4-H benediction, an Indian chant sung with hands uplifted. After announcements everyone went to bed at 11 o'clock.

SECOND DAY

Rising whistle, 6:30. Breakfast, 7:15. At 8:30 entire group went into a discussion and study session in nearby schoolhouse. District home demonstration agent in charge. Twelve interesting

*This narrative is incorporated because:

(1) It serves as an example of intensive club leadership training.

(2) The specific problems that arise in every-day club work are here presented and analyzed, and suggestions are made for their handling or solution.

(3) The conference exhibits the personal traits and characteristics of about one-seventh of the most effective club leaders of the state.

(4) The general plan of the conference is an exemplification of club work principles and technique, at least in respect of showing how the balance of work and play, of group and individual activities is fostered.

problems discussed. Five-minute intermission, with songs and stunt. Representative discussion: "Important points and problems in booklet making." At playground, games suitable for county camps demonstrated. Price of supplies and where they could be obtained was explained. Group singing. A discussion led by district home demonstration agent on best club meeting of year brought these responses: (1) an open meeting for mothers; (2) a regular Council Circle meeting with parents invited; (3) Council Circle for neighbor clubs. One county agent reported 50 adults present at one of his best open meetings. Typical May meeting given by state specialist. A demonstration, led by district agent, on "Organizing a 4-H Club." Goals for coming year discussed.

12 noon to 12:45, dinner. 12:45 to 2:00, games, recreation. District agent discussed judging teams and contests at Greenbrier Regional Fair; object: to stimulate better project work. Demonstration of simple and inexpensive game called "ring toss." District agent announced state, national prizes. State extension club specialist discoursed on county camps. Handicraft work learned at camp: decorative stitches, book racks, pocket books, 4-H pillows, basket weaving, lamp-shade making. Harder to provide class work for boys: rope making, poultry culling, game equipment, nature study, every-day manners, first aid, mechanics, camp cookery, fire building, swimming, reed-bottoming chairs. State camp dates announced. 4:30 to 5:30, recreation. 5:30, supper. After supper, informal recreation and rehearsals for stunts. 7:00, vespers—a beautiful 45-minute service on river bank. 8 to 11, Council Circle and stunts by tribes. Good singing throughout the conference, some trained voices, spontaneous spirit.

THIRD DAY

8:30, model club meeting. Personal development talk by county agent. Demonstration of sewing by three girls. Entire group resolved itself into an assumed new club.

Home demonstration agent: "Demonstrations probably are not used as much as they might be. They should not be considered only as work for a few of the best ones. Visiting clubs can put on demonstrations for new clubs."

County agent: "One of the greatest problems of the leader is the selection of projects. Where there is a large number of clubs the county agent can usually get at these problems through sectional leaders' meetings."

One leader stated that he visited each home and discussed projects with parents before selection. It was pointed out that leaders should consult county agent to see how projects fit in with county Agricultural Extension program. Demonstration of how a group can have real recreation in crowded place on rainy day. Eligibility rules for exhibition of projects at fairs. Club group exhibits discussed.

Conference closed at noon.

X. CLUB WORK AS SEEN BY A FARM MOTHER OF SIX CHILDREN WHO HAVE BEEN ACTIVE IN 4-H ENTERPRISE

The following statements give some clue to favorable parental attitudes toward 4-H club work and the effects of these attitudes. Twenty questions were submitted to a farm woman of Monroe County whose six children had had a total of 39 years of experience in 4-H club work, an average of 6½ years each. This family is exceptional in the sense that the parents and children have constantly and intelligently worked together to make the most of their 4-H club opportunities and experiences; and also in the sense that the effects are seen in the very substantial personal development of the members of the family.

With a more complete analysis of the community situation, the answer to question No. 7 might have been more favorable as respects the effect upon the community of one of the best 4-H clubs in this particular county. The informant's answer may be a suggestion to club leaders that in order to make a 4-H club of vital value to the community or institutional life, some technical knowledge of or training in community affairs should be an integral part of a club leader's equipment.

The club to which these boys and girls belonged furnished seven of the 25 All-Stars of the county.

SIGNIFICANT QUESTIONS AND ANSWERS

1. What projects were carried by your children? Beans, potatoes, turkeys, chickens, pigs, canning, sewing, bread.

2. What proportion of these projects was completed? Three-fourths.

3. What leadership (officers, etc.) activities were carried by different individuals? District leader, club agent, and local leader; president of home club; volunteer leader and president; president.

4. In what definite ways have you or your husband aided or encouraged the children in their 4-H work? My husband and I were always glad to help the children in any way we could. Provided horses to ride and food to serve, and helped with their projects. We could not help them much financially, but we showed interest and a willingness to help them.

5. Why have you considered it worth while to give this aid and encouragement? I have seen the benefit of 4-H work develop with every child. Every word of encouragement just made them strive harder and reach higher until it has really been worth while to my family.

6. In what definite ways has experience in club work been of value to your children? Club work has developed them fourfoldwise. They are not timid to appear in public. They will try to lead meetings. They are more interested in Sunday School. They have learned how to do things with their hands that I couldn't have shown them myself or never knew of at all. They have tried to build their character. For that I am very thankful.

7. In what definite ways has 4-H work benefited your community? I can't say that 4-H work has really benefited my community at all. We have no women's clubs or men's clubs. You can really see no benefit except among individuals in this community. The younger ones that have stuck through all the draw-backs and obstacles, are all.

8. What do you consider the most valuable or successful phases of 4-H work? The project and the camp life (the associations, the instruction, the handicraft, and good sportsmanship).

9. Should 4-H club members be selected or should membership be open to all interested children of the specified ages? Club work should be open to all boys and girls of specified age. Cull them in the beginning and there won't be so many quitters.

10. How can club work be made more effective and reach more boys and girls? More boys and girls could be reached with 4-H work through leadership and enthusiasm of parents and school teachers, along with their cooperation.

11. What mistakes have been made in carrying on 4-H work in your community and county? When club work first came to my home it just seemed to be "carry a project" and "got to go to camp." In our county, much stress was given to club work in the upper end and for several years we hardly existed to them. The coming of a home demonstration agent put us on the map. When she left, it was all asleep, with a few exceptions.

12. Why are there about twice as many girls as boys in 4-H work in West Virginia? It's the father's fault. Many boys are made to believe they are fit for nothing, not dependable, and don't deserve encouragement. If the fathers would be 4-H'rs the boys would most likely be too.

13. Why is 4-H work, once so flourishing in your county, now at low ebb? This county just made a poor selection of leadership, or else we are not developing much. Our school teachers are "dead." Our farmers are "set on old time methods." The young folks can't go alone. They must have an older companion and leader.

XI. STRONG POINTS AND WEAK POINTS IN THE 4-H PROGRAM IN WEST VIRGINIA

STRONG POINTS

1. *County Camps and the State Camp.* Almost without exception club leaders and members informed the field workers that they considered the county camp the most valuable single factor in the whole 4-H program. The week of intensive training in the various phases of club work seems to leave a lasting impression on those who attend. The handcraft work, the council circle, vespers, swimming, club songs, and other forms of work and recreation make a unified and effective group of activities. Many club members, now active leaders, told the field workers that they never really knew what club work was until they had gone to county camp. This remark was probably an unconscious testimony to the fact that many, perhaps the majority, of local club leaders are not themselves sufficiently trained to make it clear to the beginners in club work what it is all about.

A very real value of the county camps lies in the opportunity it gives for forming new friendships and making old ones stronger. It is the only opportunity many farm boys and girls have of learning to know other boys and girls of similar tastes, capacity, and ambitions, from other sections of the county.

The State 4-H Camp at Jackson's Mill, Lewis County, one of the strongest, best organized phases of the whole 4-H program in the state, contributes vitally to the maintenance and further development of the work.

2. *A Well-Balanced Program of Work, Including Considerable Emphasis on the Spiritual or Religious Element in Life.* The farm population in West Virginia is 98 percent native white, and Protestant in religion. Since the religious element in the 4-H program is non-sectarian, it is easier and more natural for the club leaders to emphasize this aspect than it would be in certain other states where the distribution of the population is different as to religion.

3. *The Emphasis in Club Activities Is on the Human and Social Rather than on the Technical and Economic.* There are certain aspects of West Virginia farm life (such as isolation and poorly developed social and recreational life for the young people of club age) which seem to justify a strong emphasis upon these phases of the 4-H program. This greater attention to the human and social side does not necessarily weaken the project side of the work in agriculture and home economics. One definite result of the West Virginia policy is that clubs are organized on the boy and girl basis and not on the project basis, as in some states. There are numerous examples of successful small clubs in sparsely settled territory where there could be no club at all if the organization were on the project basis.

4. *The Regional 4-H Fairs Which Have Been Made Possible by a Small State Appropriation (1929) Promise to Vitalize and Broaden 4-H Interests in a Substantial Way.* Many county fairs have been discontinued, and even where they are still carried on, a group of five or six counties makes a more stimulating basis for competition. The plan is to pay expenses of prize-winning 4-H boys and girls to these fairs. A three-day program, including recreational and educational features and training in the preparing and judging of exhibits, makes a trip to one of these regional fairs a coveted prize for farm boys and girls of the districts.

WEAK POINTS

All of the deficiencies listed can be remedied at least partially.

1. *The Percentage of Project Completions Is Too Low.* For the club year 1927-28 (the year covered for most of the data of this study) about 50 percent of the enrolled members completed their projects. The counties with small enrollments had the highest percentage of completions. The county with the largest enrollment had about 25 percent of completions.

2. *The Proportion of Boys Among the Club Members Is Too Low.* Approximately two-thirds of the total enrollment is girls. The state of Tennessee in 1927-28 had a 4-H enrollment of 24,408, almost equally divided between boys and girls. Some probable reasons for the situation in West Virginia may be: (1) Greater cost of boys' project material. (2) Most of the club supervision is usually left to the home demonstration agents in counties where there is both a man and a woman county agent. (3) The illustrated booklet, which is part of the project completion requirement, is much more attractive to girls than boys. (4) On the whole, girls' projects (baking, sewing, and canning especially) are more easily and quickly brought to completion. If a boy's pig or calf dies he is sometimes too much discouraged to continue. (5) Probably girls are conformists more than boys and respond to the persuasion or pressure of their leaders to persevere to the finish.

3. *The Period of Active Club Membership Is Too Short.* There is a serious waste of time and money in allowing such a heavy turnover in membership and such transient contacts with the club program of work.

4. *Too Much Delay in Selecting Projects.* Most clubs are organized in October or November, but a large percentage of the projects, especially the boys' projects, are not selected until the following February or March, when the enthusiasm and interest of many have waned.

5. *Not Enough Trained and Responsible Local Leaders, Especially for the Summer Season.* A relatively small outlay of money would add considerably to the supervising personnel, especially in the summer, when all crop and livestock projects are in full swing and when records and exhibits are to be completed for display at the fairs. The high mortality in club membership toward the end of the year could largely be prevented by more use of even part-time supervisors.

6. *Inflated Enrollments in a Few Counties or Districts.* One county agent declared club membership worth while if the boy or girl attends only one club meeting. His county had about 1800 members in 1927-28, one-fourth of whom completed their projects.

A certain district in another county was organized on the high pressure basis about eight years ago. Two years later there was hardly a club member left in the whole district; and in 1928 it was very difficult to organize a real 4-H club there.

7. *Too Frequent Change of County Leadership.* It is unfortunate that so few of the county workers remain in their counties long enough to get hold of the club situation by learning to know local communities, club leaders, and the various factors in the county situation which make for success or failure in the 4-H program.

8. *Inadequate Records.* In very few, if any, counties are adequate records to be found embracing a considerable number of years. Perhaps the central office of the Agricultural Extension Division could encourage more widely spread practice of keeping records if simple forms were furnished by state headquarters of 4-H work to the county and home demonstration agents and if it were made clear that the keeping of reasonably accurate and complete records is an essential part of the regular work of 4-H club supervision.

9. *Not Enough Definite Sponsoring of 4-H Club Work by Interested and Helpful Adults.* Both the Farm Bureau and the Farm Women's Bureau theoretically make the sponsoring of 4-H work a regular, integral part of their program. In fact, however, only a few local Farm Bureau or Farm Women's club units give any consistent and substantial help to their 4-H club, if there is one in the neighborhood.

10. *Too Much Dependence upon School Teachers for Local Club Leaders.* While it is true that in many respects teachers make ideal club leaders, there are inevitable handicaps in a great many cases. Perhaps the most serious handicap is that of the non-resident teacher who leaves the community just when her club needs her most. As time goes on and there are more farm men and women who have had successful experience as club members, a larger number of these should be enlisted as club leaders. Having children of their own and being permanent residents of the community, they are in a strategic position to do excellent club leadership work.

11. *In Many Cases not Enough of a Selective Process Is Used in Enrolling Club Members at the Beginning of the Year.* One of the best procedures found in this respect was that used by an enterprising young principal of a junior high school. When she started her club in the fall she made it plain that all of suitable age who were interested could enroll as temporary members. During the next six weeks she made perfectly clear, by explanation and demonstration, that club membership carried with it responsibility and hard work as well as good times in the way of hikes and picnics. At the end of the probationary period 18 of the 25 temporary members chose to continue; and in the late spring when this club was visited it was in flourishing condition and all 18 members were functioning.

The genuine success of the club mentioned above is in strong contrast to two others (in two different counties) which were organized on a free-for-all basis.

12. *Club Meetings Often Are Poorly Planned, or Hardly Planned at All.* At one of the sessions of the regional conference described in Section IX, great emphasis was properly placed on the necessity of using foresight and planning meetings at least one month ahead (allowing for changes due to unforeseen circumstances). Both the adult club leader and the club president (a boy or girl who is a member of the club) are jointly responsible for intelligent and foresighted planning of meetings. If the cooperation and respect of active boys and girls are to be retained and they are to be helped to develop character and efficiency through their 4-H activities, some way must be found to increase the proportion of genuinely successful club meetings.

ARIZ.UNIV.LIB. JUL 15 1931

BULLETIN 242 JUNE, 1931

Northern and Native-Grown Potato Seed Stock

BY K. C. WESTOVER

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

AGRICULTURAL EXPERIMENT STATION STAFF

JOHN R. TURNER, Ph. D., LL. D., President of the University
F. D. FROMME, Ph. D. .....Dean and Director
GERALD JENNY, M. S., Agricultural Editor....JOHN C. JOHNSTON, Chief Clerk

AGRONOMY AND GENETICS
R. J. Garber, Ph. D.
Agronomist and Geneticist
E. P. Deatrick, Ph. D.
Associate Agronomist
W. H. Pierre, Ph. D.
Associate Agronomist
T. C. McIlvaine, Ph. D.†
Assistant Agronomist
M. M. Hoover, M. S.
Assistant Agronomist
G. G. Pohlman, Ph. D.
Assistant Agronomist
H. K. Rowley, M. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY
E. A. Livesay, D. Sc.
Animal Husbandman
C. V. Wilson, M. S.
Assistant Animal Husbandman
J. H. Longwell. M. A.
Assistant Animal Husbandman
J. H. Rietz, D. V. M. **
Associate Veterinarian
R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman

CHEMISTRY
R. B. Dustman, Ph. D.
Agricultural Chemist
Chas. E. Weakley, Jr., M. A.
Assistant Chemist
L. P. Hansen, Ph. D.
Assistant Chemist
T. B. Leith, M. S.**
Assistant Chemist
I. J. Duncan, B. S.
Assistant in Agricultural Chemistry

DAIRY HUSBANDRY
H. O. Henderson, Ph. D.
Dairy Husbandman
L. M. Thurston, Ph. D.
Assistant Dairy Husbandman
K. S. Morrow, M. S.
Assistant Dairy Husbandman
L. F. Sutton, B. S. Agr.‡
Assistant Dairy Husbandman
R. A. Ackerman, M. S. Agr.
Assistant in Dairy Husbandry

ENTOMOLOGY
L. M. Peairs, Ph. D.
Entomologist
W. E. Rumsey, B. S.**
State Entomologist
Edwin Gould, B. S. Agr.
Assistant in Entomology

FARM ECONOMICS
A. J. Dadisman, Ph. D.
Farm Economist
F. D. Cornell, Jr., M. S.
Assistant Farm Mechanician
W. W. Armentrout, M. S.
Assistant Farm Economist
R. O. Stelzer, B. S.
Assistant in Farm Economics

HOME ECONOMICS
Rachel H. Colwell, M. A.
Home Economist
Hazel C. Cameron, M. A.
Research Specialist in Nutrition

HORTICULTURE
H. E. Knowlton, Ph. D.
Horticulturist
K. C. Westover, M. S. Agr.
Assistant Horticulturist
F. W. Craig, M. S. Agr.**
Assistant Horticulturist
Leif Verner, M. S.
Assistant Horticulturist
M. B. Hoffman, M. S.
Assistant in Horticulture
E. N. McCubbin, M. A.
Assistant in Horticulture
A. P. Dye, M. S. Agr.
Assistant in Horticulture

PLANT PATHOLOGY
C. R. Orton, Ph. D.
Plant Pathologist
Anthony Berg, M. S.
Associate Plant Pathologist
L. H. Leonian, Ph. D.
Associate Plant Pathologist
F. J. Schneiderhan, M. S.
Associate Plant Pathologist
E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY
Horace Atwood, M. S. Agr.
Poultry Husbandman
T. B. Clark, B. S. Agr.
Assistant in Poultry Husbandry

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Experiment Farm, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

Northern and Native-Grown Potato Seed Stock

by K. C. WESTOVER

THE POTATO is one of the most valuable cash crops grown in West Virginia. In the last fifteen years much progress has been made both in the culture and the marketing of the crop until now its production is considered one of the highly specialized industries of the state. The entire commercial crop is consumed as food, and no attention is given to the production of seed stock. The raising of early market potatoes is confined principally to the Ohio and Kanawha River valleys, while the late crop is, for the most part, produced in the upland sections (Preston, Randolph, Tucker, Hampshire, and Pendleton counties). Potato yields at present compare favorably with those of the well-established main-crop producing sections of the North. In view of the fact that several growers at different altitudes have had little difficulty in maintaining high-yielding seedstocks by hill selection, there has naturally arisen a question as to the practicability of producing potato seedstocks in West Virginia under the assumption that the favorable growing conditions attributed to the more northern latitudes might, in this respect, be paralleled by those in the higher altitudes of West Virginia. A brief résumé of the literature pertinent to the question may, at this point, be of interest.

SURVEY OF LITERATURE

Stuart *(8)* while at Vermont used European varieties obtained from Scotch and English seedsmen in a series of tests in progress from 1905 to 1910, to determine the "extent and persistency of place-effect on environmental influences on the potato through successive generations." He found from his observations of eight varieties for six seasons, of three varieties for five seasons, of one variety for three seasons, and of one variety for two seasons, that invariably the Scotch seed outyielded seed produced in England. He concluded that northern-grown seed was superior to that grown farther south; in fact, that one year's removal from the North caused noticeable deterioration, which became more rapid in the succeeding years. Several years in the North were required to regenerate the stocks to their original vigor.

In this respect a topographical study of England and Scotland reveals that there is only a small area, extending from the central to the north-central part of England, in which the altitude exceeds 2000 feet. England is, for the most part, a relatively low, rolling countryside. On the other hand, the greater part of the area of Scotland is from 2000 to 4000 feet above sea level. Very little is low-lying or level. Thus it is possible that Stuart's findings in these experiments may have been due to altitude as well as latitude, or perhaps a combination of the effects of both. This author also cites the work of Minott, who, when at the Vermont Station, collaborated with the Maryland Station during 1888 and 1889 in making comparative tests at each station of several varieties which had previously been grown in the same locality. The northern-grown seed outyielded the Maryland-grown stock by 53 percent.

Wessels and Hartwell *(9)*, reviewing early experiments conducted at the Rhode Island Station, which dealt with the relative value of northern and southern-grown stocks, state that the average loss from the use of the southern-grown stock was 66 bushels per acre, some 123 comparisons having been made during the course of the experiments. This decrease resulted in spite of attempts in many cases to maintain yields of tuber-unit selection. Schultz and Folsom *(6)* in 1925 found that the farther south potatoes were grown, the greater was the percentage of disease. Martin *et al (5)* in 1925 reported experiments conducted for three years, in which the same strains of Maine vs. southern New Jersey fall-crop seed and their progenies were compared each year in both states. Green Mountain and Irish Cobbler varieties were used. Cobblers from New Jersey were a few days slower in germinating and even longer in maturing, but no difference was noted with the Green Mountain variety. In general the New Jersey seedstocks were smaller and less mature. Maine seed produced more stems per plant, but this was offset by a greater percentage of disease. The yields were not significantly different.

In 1922 Bevan *(1)* wrote that the growers on the Plains of Cyprus, on the Isle of Cyprus in the Mediterranean, prefer seed potatoes which have grown a year in the cool climate high in the mountains. This is supposed to renew or prolong the vigor of the stock. Williams and Mathews *(10)*, as a result of trials run for six years in eastern Carolina, state that certified mountain-grown Cobblers from the North Carolina mountain sections are equal to Main certified Cobblers in both earliness and yield. Smith *(7)* in trials on the eastern shore of Virginia compared Virginia mountain-grown Irish Cobblers and Green Mountain seed potatoes with those of the same varieties from Maine and Prince Edward Island, and found the Virginia seed to yield more, to contain less disease, and to show a decidedly more healthy appearance in the field. The Prince Edward Island stocks were next best.

Jehle and Oswald *(2)* have recently reported tests in which they compared seedstocks from northern and western sources, from the mountains of western Maryland and Virginia, as well as New Jersey fall-grown and home-grown seed stocks. Plantings were made in Washington County, Maryland. The largest yields were from northern-grown certified seed, with mountain-grown certified seed second and fall-grown certified seed third. These results indicate that healthy and vigorous stocks are most likely to be obtained in the North or in the higher altitudes of sections farther south.

This brief review of the literature would indicate that there is a reasonable possibility of raising good seed-potato stocks in the higher altitudes of West Virginia.

OBJECTS

The experiments reported herein, in progress from 1921 to 1924, inclusive, were planned with a two-fold object:

(1) The determination of the relative yields of a recommended northern Smooth Rural potato seedstock and the native strains of the same variety from a high and a medium altitude, when all are grown together at several altitudes in the state and in two latitudes out of the state; and

(2) The observation of possible similarity of effect of change of latitude as contrasted with change in altitude in West Virginia.

MATERIALS AND METHODS

The northern-grown seed used in these trials was produced by O. J. Brustad of Fosston, Minnesota, and certified by the Minnesota Department of Agriculture. This was the northernmost source of certified Smooth Rurals in that state in 1920.

The high-altitude Smooth Rural strain was purchased from J. J. Betler, of Helvetia, in Randolph County, West Virginia, who by rigid hill selection had maintained the strain in a vigorous condition for seven years. Helvetia is approximately 3000 feet above sea level.

The low-altitude Smooth Rural strain was procured from Frank Kelly of Little Falls, in Monongalia County, West Virginia. It was the result of several years of close selection and was regarded as superior by neighboring growers. The Kelly farm is 1200 feet above sea level.

The cooperation of the Kentucky and the Minnesota Stations was obtained in the early winter of 1922. Their participation in the project was of particular value since they are located at the extreme latitudes of the late or main-crop producing sections of the country and were believed to have representative climates for these latitudes.

In West Virginia the trials were run at the Horticulture Farm of the Agricultural Experiment Station in Morgantown and at three different altitudes in the late or main-crop areas of the state, where seedstock would most likely be grown were it found practicable.

As first planned, the collaborating stations were to exchange seedlots* with the West Virginia Station each season and at the same time to continue those lots already received. This procedure was to continue for four seasons, thus affording comparative trials of seedlots which had originated at one station, grown from one to four years away, and then returned to the originating station for final trial. This arrangement was impossible to follow; for that reason the data from the different experiments will be considered separately by years.

With few exceptions the same planting scheme was used in all trials. This will be described in detail in the consideration of the several trials. The three strains of each seedlot occurred in the plantings in this sequence: (1) the low-altitude strain, (2) the northern-grown strain, and (3) the high-altitude strain. In most of the trials this arrangement was replicated four or more times in order to permit statistical analysis by Student's Method *(3)*, *(4)*, in which the probability of the difference occurring between the paired members of the trial are expressed in odds. Odds of 31 or more to 1 are considered significant.

The 1921 Trial

In 1921 a planting of the three strains was made at Morgantown at an altitude of about 1050 feet, to obtain sufficient seedstock to carry on subsequent tests. The area selected for the planting was moderately level. Four rows, 600 feet long, of each of the strains were planted in the following sequence: (1) the northern-grown strain, (2) the high-altitude strain, and (3) the low-altitude strain. The area was uniformly fertilized, planted, and cultivated. No consistent differences between the strains could be observed during the growing season. The crop was dug by machine and the potatoes were "picked" in consecutive 10-foot lengths of row. The total yields were weighed to quarter-pound accuracy. This procedure permits of the combination of 10-foot increments into plots of different sizes and shapes, and allows for many more plot distributions in the analysis of the data.

Table 1 shows the yield differences in bushels per acre between the strains for two plot distributions, together with the significance of these differences. The yields of corresponding consecutive 50-foot lengths of the two center rows planted with each strain were combined. The first, third, fifth, seventh, and ninth plots of each strain

*A seedlot as here used is a sufficient quantity of each of the three seed strains, used together in equal amounts, to plant the necessary area for a single trial or test. The members of a seedlot have been grown under similar conditions.

composed the first distribution or grouping. The second, fourth, sixth, eighth, and tenth plots formed the second grouping.

TABLE 1.—*Comparison of total yield of seed strains grown on an increase planting in* 1921 *at the Horticulture Farm, Morgantown, W. Va. Altitude* 1050 *feet*

Comparison	Number of series	Average yields in bu. per acre	Yield differences in bu. per acre	Odds
FIRST GROUPING				
Northern-grown vs. high-altitude	5	191.4—271.8	80.4	632:1
Northern-grown vs. low-altitude	5	191.4—191.1	0.3	None
High-altitude vs. low-altitude	5	271.8—191.1	80.7	574:1
SECOND GROUPING				
Northern-grown vs. high-altitude	5	176.3—269.8	93.5	537:1
Northern-grown vs. low-altitude	5	176.3—214.2	37.6	295:1
High-altitude vs. low-altitude	5	269.8—214.2	55.6	62:1

In both groupings the high-altitude strain outyielded the northern-grown and low-altitude strains significantly; however, there was some question as to the superiority of the low-altitude over the northern-grown stock, since in the first grouping there is apparently no measurable difference in yield, while in the second, the difference is significantly in favor of the low-altitude strain. In this trial the high-altitude strain was superior, with some question as to which of the others rated second.

It is possible that these distributions may be regarded as not systematic and as giving an untrue sampling of the area because the plots planted from a single strain occurred at regular intervals from front to rear and not across the area from right to left. These data are considered of value nevertheless, since the area was some 15 times as long as it was wide and the probability of soil heterogeneity was obviously much greater in this direction than in the short way of the planting.

THE 1922 TRIALS

The stocks grown in 1921 on the Station farm at Morgantown were held in controlled storage until early spring, when seedlots were sent to the Kentucky and Minnesota Stations for trial. Plantings were also made at several altitudes in West Virginia in addition to the one made at Morgantown. The description of the several trials, together with a discussion of the data obtained, follow:

TRIAL NO. 2. KENTUCKY AGRICULTURAL EXPERIMENT STATION, LEXINGTON, KY. ALTITUDE 989 FEET

This planting, made July 10, was probably too early, since this particular season proved to be exceptionally dry and hot. This in part may be responsible for the poor germination that occurred. Three replications were planted in a soil of only moderate fertility. The hill system of planting was used, the rows consisting of 45 hills

each. Little spindling sprout was found although all the stock showed leaf roll. At harvest time both total yields and U. S. No. 1 grade were recorded in pounds. (See Table 2.)

TABLE 2.—*Comparison of actual and corrected yields of No. 1's and total yields from seedlot grown at Morgantown in* 1921 *and at the Kentucky Station in* 1922. *Altitude* 989 *feet*

Comparison	Number of series	Average yields in bu. per acre	Yield differences in bu. per acre	Odds
ACTUAL YIELDS OF No. 1's				
Northern-grown vs. high-altitude	4	58.3—46.9	11.4	10:1
Northern-grown vs. low-altitude	4	58.3—46.4	11.9	9:1
High-altitude vs. low-altitude	4	46.9—46.4	0.5	None
ACTUAL TOTAL YIELDS				
Northern-grown vs. high-altitude	4	82.5—77.1	5.4	19:1
Northern-grown vs. low-altitude	4	82.5—60.6	21.9	2:1
High-altitude vs. low-altitude	4	77.1—60.6	16.5	8:1
CORRECTED YIELDS OF No. 1's				
Northern-grown vs. high-altitude	4	140.5—130.4	10.1	2:1
Northern-grown vs. low-altitude	4	140.5—145.7	5.2	5:1
High-altitude vs. low-altitude	4	130.4—145.7	15.3	3:1
CORRECTED TOTAL YIELDS				
Northern-grown vs. high-altitude	4	100.0— 98.7	1.3	None
Northern-grown vs. low-altitude	4	100.0—115.5	15.5	88:1
High-altitude vs. low-altitude	4	98.7—115.5	16.8	4:1

On the basis of actual stand the northern-grown and high-altitude strains outyielded the low-altitude strains. However, on the basis of a perfect stand the low-altitude strains outranked the northern-grown and the high-altitude strains in the order given. This would suggest that the low-altitude sets which grew produced more than those of the other strains, although the only significant differences occurred in total yield between the northern-grown and the low-altitude stocks. Two seedlots from this planting were taken at harvest. One was held in storage at Lexington and the other was sent to West Virginia.

TRIAL NO. 3. HORTICULTURE FARM, MORGANTOWN, W. VA.

Five replications of a planting made up of a 70-foot row from each of the strains were grown. Single guard rows of the same seedstocks were employed as the end rows to eliminate border influences. The planting was harvested September 30th and the total yields per plot row were taken to quarter-pound accuracy.

TABLE 3.—*Comparison of total yields of the seedlot carried over from* 1921 *and grown in* 1922 *at Morgantown, W. Va. Altitude* 1050 *feet*

Comparison	Number of series	Average yields in bu. per acre	Yield differences in bu. per acre	Odds
Northern-grown vs. high altitude	6	228.6—283.1	54.5	85:1
Northern-grown vs. low-altitude	6	228.6—306.3	77.1	132:1
High-altitude vs. low-altitude	6	283.1—306.3	23.2	4:1

Table 3 shows that the low-altitude and the high-altitude stocks were significantly superior in total yield to the northern-grown strain in the order given. The comparison of the native strains gave a considerable difference in favor of the low-altitude strain. However, because of the variation in the yields, little confidence is to be placed in this difference. Both native strains were better in this trial, the low-altitude strain ranking first.

TRIAL NO. 4. FARM OF FRANK KELLY, LITTLE FALLS, W. VA. ALTITUDE 1200 FEET

The planting of this trial was similar to that at the Horticulture Farm with the exception that the row length was 50 feet instead of 70 feet. The seedlot was from the same source and the same sort of data were taken at harvest. (See Table 4.)

TABLE 4.—*Comparison of total yields of seedlot carried over from the* 1921 *planting at Morgantown and grown at Little Falls, W. Va., in* 1922. *Altitude* 1200 *feet*

Comparison	Number of series	Average yields in bu. per acre	Yield differences in bu. per acre	Odds
Northern-grown vs. high-altitude	6	77.0—92.6	15.6	51:1
Northern-grown vs. low-altitude	6	77.0—90.9	13.9	50:1
High-altitude vs. low-altitude	6	92.6—90.9	1.7	2:1

Significant differences in yield occurred in favor of both the high-altitude and the low-altitude strains over that from the North. The high-altitude strain showed a slight increase over the low-altitude stock, but the difference was of no significance.

TRIAL NO. 5. FARM OF R. F. PAYNE, PHILIPPI, W. VA. ALTITUDE 1550 FEET

The planting, identical in plan with that used on the Kelly Farm, was planted with the same seedstock. The same procedure was employed at harvest. No marked differences in growth could be determined from observation during the season.

TABLE 5.—*Comparison of total yields of seedlot carried over from the* 1921 *planting at Morgantown and grown at Philippi, W. Va., in* 1922. *Altitude* 1550 *feet*

Comparison	Number of series	Average yields in bu. per acre	Yield differences in bu. per acre	Odds
Northern-grown vs. high-altitude	6	154.5—170.8	16.3	68:1
Northern-grown vs. low-altitude	6	154.5—187.3	32.8	3999:1
High-altitude vs. low-altitude	6	170.8—187.3	16.5	209:1

Table 5 shows that the low-altitude strain was markedly superior to both the high-altitude and the northern-grown stocks. The high-altitude was also significantly better than the northern-grown seed.

TRIAL NO. 6. FARM OF W. C. WOLFE, CLIFTON MILLS, W. VA. ALTITUDE 1950 FEET

The same planting plan was used here as on the Kelly and Payne farms, and similar data were taken at harvest. It was thought that during the growing season the high-altitude stock was perhaps a little deeper green in color than the other strains. However, little importance is attributed to this observation.

TABLE 6.—*Comparison of total yields of seedlot carried over from the* 1921 *planting at Morgantown and grown at Clifton Mills, W. Va., in* 1922. *Altitude* 1950 *feet*

Comparison	Number of series	Average yields in bu. per acre	Yield differences in bu. per acre	Odds
Northern-grown vs. high-altitude	6	261.7—273.3	43.6	9:1
Northern-grown vs. low-altitude	6	261.7—229.7	32.0	31:1
High-altitude vs. low-altitude	6	273.3—229.7	11.6	124:1

Table 6 shows that the high-altitude strain slightly outyielded the northern-grown stock. Both the high altitude and the northern-grown stocks significantly out-yielded the low-altitude strain in the order given.

TRIAL NO. 7. MINNESOTA AGRICULTURAL EXPERIMENT STATION, UNIVERSITY FARM, ST. PAUL, MINN. ALTITUDE 940 FEET

Due to lack of space only a single 66-foot row of each strain of the seedlot sent from West Virginia was planted. These three rows were planted in an area devoted to trials of sample lots of certified Minnesota seed. Three systematically distributed plots of each sample lot were planted. The probable error of the certified sample which flanked these strains was assumed to be closely approximate to that which would have occurred had the seedlot strains been given a similar distribution. These yields were as follows:

Northern-grown .....185.4 ± 19.0 bushels per acre
High-altitude .....150.4 ± 15.5 bushels per acre
Low-altitude .....219.0 ± 22.0 bushels per acre

Continuing the assumption that these probable errors are closely approximate and that these yields give a fairly accurate mean of the yields of several plots systematically distributed, the differences between these assumed means were found to be insignificant.

THE 1923 TRIALS

Much the same procedure was continued in 1923 as in 1922: i. e., trials planted from seedlots produced at the Station farm in 1922 were made at Morgantown and at several altitudes in the state.

TRIAL NO. 8. EXPERIMENT STATION, LEXINGTON, KY.

The seedlot used in this planting was grown at Morgantown in 1922 from the initial stocks carried at this Station. It was held in cold storage over winter and sent to Kentucky, where it was planted on July 15th. Four replications of a planting made up of a single row of 27 hills from each seed strain were grown. Prof. A. J. Olney, our collaborator, reported that both the stand and the yield per hill were disappointing, particularly in the case of the high-altitude strain. He was unable to account for the low germination. When the plots were harvested on October 26th, total yields and the yields of No. 1 grade were recorded. Table 7 gives the results of this trial.

TABLE 7.—*Comparison of yields of seedlot from the* 1922 *planting at Morgantown grown at Kentucky in* 1923. *Altitude* 989 *feet*

Comparison	Number of series	Average yields in bu. per acre	Yield differences in bu. per acre	Odds
YIELD OF No. 1's				
Northern-grown vs. high-altitude	5	26.1—19.2	6.9	3:1
Northern-grown vs. low-altitude	5	26.1—30.8	4.7	3:1
High-altitude vs. low-altitude	5	19.2—30.8	11.6	18:1
TOTAL YIELDS				
Northern-grown vs. high-altitude	5	46.1—39.2	6.4	2:1
Northern-grown vs. low-altitude	5	46.1—63.2	17.1	13:1
High-altitude vs. low-altitude	5	39.2—63.2	23.5	8:1

None of the yield differences in this trial is significant, although there is a slight indication that the low-altitude strain gave better yields of both No. 1's and total yields than the high-altitude and northern-grown strains. The northern-grown and the high-altitude strains produced a greater quantity of tubers which were out of grade, as shown in the comparison of the total yields with the No. 1 yield differences. The results check closely with the corrected yields of the planting made at the same station in 1922.

TRIAL NO. 9. HORTICULTURE FARM, MORGANTOWN, W. VA.

Thirty-five replications of a planting made up of a single 30-foot row of each of the three strains were planted on April 16th from the original stocks maintained at the Station farm. The total yields were recorded in pounds. In the analysis of these data several systematic groupings of the different plot series were made. The first group used in these comparisons consisted of the initial planting and every sixth series thereafter. The second grouping comprised the first replication of the basal planting and every sixth series thereafter. This system of grouping was continued until all the series were included. Table 8 gives the significance of the yield differences for these groupings.

There were no significant differences between the yields of the different stocks in any of the groupings. However, there was a tendency for the high-altitude strain to be superior to both the northern-grown and the low-altitude strains. No appreciable difference in yields existed between the northern and low-altitude strains. This method of analysis is supported by the comparison of the means of the total yields of the entire planting of 36 series. Table 9 gives the differences in mean yields obtained by Bessel's formula, together with the significance of these differences.

The results by both methods of analysis agree very closely.

TABLE 8.—*Comparisons of total yields from six systematic distributions composed of six series each of the* 1923 *trial at Morgantown planted with seedstock maintained at the Horticulture Farm. Altitude* 1050 *feet*

Distribution composed of series number	Comparison	Average yield in bu. per acre	Yield differences in bu. per acre	Odds
1, 7, 13, 19, 25, 31	N-grown vs. hi-alt	59.0—69.7	10.7	18:1
	N-grown vs. lo-alt	59.0—67.8	8.8	9:1
	Hi-alt vs. lo-alt	69.7—67.8	1.9	2:1
2, 8, 14, 20, 26, 32	N-grown vs. hi-alt	50.3—51.8	1.5	2:1
	N-grown vs. lo-alt	50.3—53.2	2.9	2:1
	Hi-alt vs. lo-alt	51.8—53.2	1.4	1:1
3, 9, 15, 21, 27, 33	N-grown vs. hi-alt	53.7—59.0	5.3	9:1
	N-grown vs. lo-alt	53.7—45.5	8.2	4:1
	Hi-alt vs. lo-alt	59.0—45.5	13.5	10:1
4, 10, 16, 22, 28, 34	N-grown vs. hi-alt	57.6—61.0	3.4	3:1
	N-grown vs. lo-alt	57.6—56.6	1.0	2:1
	Hi-alt vs. lo-alt	61.0—56.6	4.4	3:1
5, 11, 17, 23, 29, 35	N-grown vs. hi-alt	50.3—50.3	None	None
	N-grown vs. lo-alt	50.3—49.9	0.4	1:1
	Hi-alt vs. lo-alt	50.3—49.9	0.4	1:1
6, 12, 18, 24 30, 36	N-grown vs. hi-alt	65.8—74.1	8.3	4:1
	N-grown vs. lo-alt	65.8—65.8	None	None
	Hi-alt vs. lo-alt	74.1—65.8	8.3	4:1

TABLE 9.—*Comparison of mean total yields for each strain from the trial planted on the Horticulture Farm at Morgantown in* 1923. *Altitude* 1050 *feet*

Comparison	Number of series	Mean yields in bu. per acre	Yield differences in bu. per acre	Odds
Northern-grown vs. high-altitude	36	58.6±2.2—62.4±2.5	3.8±3.3	1.4:1
Northern-grown vs. low-altitude	36	58.6±2.2—58.6±2.1	None	None
High-altitude vs. low-altitude	36	62.4±2.5—58.6±2.1	3.8±3.2	1.4:1

TRIAL NO. 10. HORTICULTURE FARM, MORGANTOWN, W. VA.

This trial was planted with a seedlot returned from Lexington, Kentucky, which had been grown at Morgantown in 1921 and in Lexington in 1922. The trial included nine replications of a planting composed of a 30-foot row of each of the three strains. Table 10 summarizes the results of this trial.

TABLE 10.—*Comparison of total yields of the* 1923 *trial at Morgantown planted with the seedlot grown in West Virginia in* 1921 *and in Kentucky in* 1922. *Altitude* 1050 *feet*

Comparison	Number of series	Average yields in bu. per acre	Yield differences in bu. per acre	Odds
Northern-grown vs. high-altitude	10	64.9—75.5	10.6	113:1
Nortern-grown vs. low-altitude	10	64.9—84.2	19.3	Abs. signif.
High-altitude vs. low-altitude	10	75.5—84.2	8.7	15:1

Both the high and the low-altitude strains outyielded the northern-grown strains. The low-altitude strain was apparently superior to the high although the difference between them was not significant.

TRIAL NO. 11. HORTICULTURE FARM, MORGANTOWN, W. VA.

This trial was planted with a seedlot received from the Minnesota Station which had been grown in West Virginia in 1921 and at Minnesota in 1922. The planting included five series, each composed of a 30-foot row of each of the strains. The results of this trial are summarized in Table 11.

TABLE 11.—*Comparison of yields of the* 1923 *trial at Morgantown planted with the seedlot grown in West Virginia in* 1921 *and in Minnesota in* 1922. *Altitude* 1050 *feet*

Comparison	Number of series	Average yields in bu. per acre	Yield differences in bu. per acre	Odds
Northern-grown vs. high-altitude	5	73.1—68.7	4.4	4:1
Nortern-grown vs. low-altitude	5	73.1—65.8	7.3	5:1
High-altitude vs. low-altitude	5	68.7—65.8	2.9	3:1

There were no significant differences between the yields of these strains. However, there is a slight indication in favor of the northern-grown and the high-altitude in the order given.

TRIAL NO. 12. FARM OF R. F. PAYNE, PHILIPPI, W. VA.

Eight replications of a planting consisting of a single 30-foot row from each of the seed strains were planted. This seedlot had been maintained at Morgantown since 1921. Table 12 gives the differences between the total yields.

TABLE 12.—*Comparison of total yields of seedlot carried at Morgantown in* 1921 *and* 1922 *and grown at Philippi, W. Va., in* 1923. *Altitude* 1550 *feet*

Comparison	Number of series	Average yields in bu. per acre	Yield differences in bu. per acre	Odds
Northern-grown vs. high-altitude	9	218.8—234.3	15.5	28:1
Northern-grown vs. low-altitude	9	218.8—258.9	40.1	155:1
High-altitude vs. low-altitude	9	234.3—258.9	24.6	15:1

Both West Virginia strains outyielded the northern stock in this trial, the low-altitude being significantly better. The differences between the high-altitude and the northern-grown, and between the low-altitude and the high altitude, are wide but not significant.

TRIAL NO. 13. FARM OF W. C. WOLFE, CLIFTON MILLS, W. VA.

Five replications of a planting made up of a single 30-foot row of each strain were planted. The seedlot came from the stocks maintained on the Horticulture Farm at Morgantown. Table 13 summarizes the results of this trial.

TABLE 13.—*Comparison of total yields of seedlot carried at Morgantown in* 1921 *and* 1922 *and grown at Clifton Mills, W. Va., in* 1923. *Altitude* 1950 *feet*

Comparison	Number of series	Average yields in bu. per acre	Yield differences in bu. per acre	Odds
Northern-grown vs. high-altitude	6	243.4—290.9	47.5	735:1
Northern-grown vs. low-altitude	6	243.4—267.7	24.3	72:1
High-altitude vs. low-altitude	6	290.9—267.7	23.2	14:1

Both strains of West Virginia seedstock were distinctly superior in this trial—the high-altitude strain ranking first. However, the yield differences between these strains were not significant.

TRIAL NO. 14. NORTHEAST MINNESOTA SUBSTATION, DULUTH, MINN. ALTITUDE 1133 FEET.

The seedlot used in the planting of this trial had been grown at the West Virginia Station for two years and shipped to the Minnesota Substation in the spring of 1923. Three replications of a planting consisting of a single 50-foot row of each strain were planted. Table 14 shows yield comparisons made between these stocks.

TABLE 14.—*Comparison of total yields of trial at Duluth, Minnesota, in* 1923, *planted with seedlot carried at Morgantown in* 1921 *and* 1922. *Altitude* 1133 *feet*

Comparison	Number of series	Average yields in bu. per acre	Yield differences in bu. per acre	Odds
Northern-grown vs. high-altitude	4	429.8—233.8	196.0	25:1
Northern-grown vs. low-altitude	4	429.8— 94.9	334.9	171:1
High-altitude vs. low-altitude	4	233.8— 94.9	138.9	101:1

The northern-grown and high-altitude strains outyielded the low-altitude strain significantly. Even though there is an indication of the superiority of the northern-grown over the high-altitude strain the difference in their total yields is not significant.

THE 1924 TRIALS

In 1924 trials were made only at Morgantown from seedlots taken from the 1923 plantings at the collaborating stations and from the stocks which had been continued at the Horticulture Farm since 1921.

TRIAL NO. 15. HORTICULTURE FARM, MORGANTOWN, W. VA.

The trial consisted of 13 series of a planting composed of a 30-foot row of each of the strains. This seed stock had been maintained at Morgantown since 1921. Table 15 summarizes the results of this trial.

TABLE 15.—*Comparison of yields of the planting at the Horticulture Farm in* 1924 *from the original seedstocks carried at Morgantown since* 1921. *Altitude* 1050 *feet*

Comparison	Number of series	Average yields in bu. per acre	Yield differences in bu. per acre	Odds
YIELD OF No. 1's				
Northern-grown vs. high-altitude	13	80.1—98.3	18.2	198:1
Northern-grown vs. low-altitude	13	80.1—91.0	10.9	5:1
High-altitude vs. low-altitude	13	98.3—91.0	7.3	3:1
TOTAL YIELDS				
Northern-grown vs. high-altitude	13	137.0—122.9	14.1	133:1
Northern-grown vs. low-altitude	13	137.0—152.5	15.5	10:1
High-altitude vs. low-altitude	13	122.9—152.5	29.6	11:1

The high-altitude strain significantly outyielded the northern-grown strain both in yield of No. 1's and in total yields. The low-altitude yielded slightly more also, but not enough to be considered as conclusively better. There was no significance in yield between the native strains, although the high-altitude gave a slightly higher yield.

TRIAL NO. 16. HORTICULTURE FARM, MORGANTOWN, W. VA.

The seedstock used in this trial was grown in 1921 and 1922 at Morgantown, in 1923 at Duluth, Minnesota, and returned to Morgantown in 1924. The planting was made up of four replications of a series composed of a single 30-foot row of each of the strains.

TABLE 16.—*Comparison of yields of seedstocks carried at Morgantown in* 1921 *and* 1922, *at Duluth, Minn., in* 1923, *and grown at Morgantown in* 1924. *Altitude* 1050 *feet*

Comparison	Number of series	Average yields in bu. per acre	Yield differences in bu. per acre	Odds
YIELD OF No. 1's				
Northern-grown vs. high-altitude	5	159.2—165.5	6.3	None
Northern-grown vs. low-altitude	5	159.2—134.6	24.6	4:1
High-altitude vs. low-altitude	5	165.5—134.6	30.9	32:1
TOTAL YIELDS				
Northern-grown vs. high-altitude	5	254.1—244.4	9.7	2:1
Northern-grown vs. low-altitude	5	254.1—218.8	35.3	7:1
High-altitude vs. low-altitude	5	244.4—218.8	25.6	7:1

Table 16, in which the results of Trial 16 are given, shows the only significant difference in yield of No. 1's between the West Vir-

ginia strains to occur in favor of the high-altitude strain. Apparently the low-altitude strain was poorest. There was no appreciable difference in the yield of No. 1's and the total yields between the northern-grown and the high-altitude strains.

TRIAL NO. 17. HORTICULTURE FARM, MORGANTOWN, W. VA.

The description of the seedstock used in this trial as well as the planting plan employed are similar to that of Trial 16, except that the seedlot had been one year in Kentucky and that five replications of the basal planting were employed instead of four. Table 17 summarizes the results of this trial.

TABLE 17.—*Comparison of yields of seedlot carried at Morgantown during* 1921 *and* 1922, *at Lexington, Ky., in* 1923, *and grown at Morgantown in* 1924. *Altitude* 1050 *feet*

Comparison	Number of series	Average yields in bu. per acre	Yield differences in bu. per acre	Odds
YIELD OF No. 1's				
Northern-grown vs. high-altitude	6	105.0—124.9	19.9	10:1
Northern-grown vs. low-altitude	6	105.0—109.4	4.4	2:1
High-altitude vs. low-altitude	6	124.9—109.4	15.5	10:1
TOTAL YIELDS				
Northern-grown vs. high-altitude	6	184.4—203.8	19.4	6:1
Northern-grown vs. low-altitude	6	184.4—171.8	12.6	2:1
High-altitude vs. low-altitude	6	203.8—171.8	32.0	14:1

No significant differences between yields occurred, although the high-altitude and northern-grown strains produced more in the order named.

At attempt has been made in Table 18 to summarize the results obtained during the course of these trials. The one carried on at University Farm, St. Paul, Minnesota, in 1922, has been included in the table because of the consistency of the results with those of the other trials in which the seedlots have been given the same treatment. However, the results of this trial are considered of little value because of the limited data available. They are not included in the discussion.

Table 18 shows the high-altitude strain to have outyielded the northern-grown strain in 11 of the 16 trials. The differences in its favor were significant in six of these trials. In two of the five trials remaining in which the northern-grown stock yielded most, the differences were significant. The rating of these strains in the trials run in West Virginia shows the high-altitude strain to have placed first in seven trials and second in five, while the northern-grown placed first in two and second in four trials. When all the trials are included, the high-altitude strain placed first in seven and second in seven, while the northern-grown placed first in four and second in five trials.

TABLE 18.—*Summary of results of seventeen trials (1921 to 1924, inclusive) planted with identical strains at four altitudes in West Virginia and at the Kentucky and Minnesota Stations*

Trial number	Year	Location of planting	Altitude	Comparison†			Rank of Strains			Source of seedstock	Treatment
				N-grown vs. hi-alt	N-grown vs. lo-alt	Hi-alt vs. lo-alt	N-grown	Hi-alt	Lo-alt		
1	1921	Morgantown, W. Va.	1050	**Hi-alt**	Lo-alt	**Hi-alt**	3	1	2	Original sources	Increase
2	1922	Lexington, Ky.*	989	N-grown	N-grown	Hi-alt	1	2	3	Trial 1	At Morgantown 1 year
3	1922	Morgantown, W. Va.	1050	**Hi-alt**	**Lo-alt**	Lo-alt	2	3	1	Trial 1	At Morgantown 1 year
4	1922	Little Falls, W. Va.	1200	Hi-alt	**Lo-alt**	Hi-alt	3	1	2	Trial 1	At Morgantown 1 year
5	1922	Philippi, W. Va.	1550	**Hi-alt**	**Lo-alt**	**Lo-alt**	3	2	1	Trial 1	At Morgantown 1 year
6	1922	Clifton Mills, W. Va.	1950	Hi-alt	**N-grown**	**Hi-alt**	2	1	3	Trial 1	At Morgantown 1 year
7‡	1922	University Farm, Minn.**	940	N-grown	Lo-alt	Lo-alt	2	3	1	Trial 1	At Morgantown 1 year
8	1923	Lexington, Ky.*	989	N-grown	Lo-alt	Lo-alt	2	3	1	Trial 3	At Morgantown 2 years
9	1923	Morgantown, W. Va.	1050	Hi-alt	N-grown	Hi-alt	2	1	3	Trial 3	At Morgantown 2 years
10	1923	Morgantown, W. Va.	1050	**Hi-alt**	**Lo-alt**	Lo-alt	3	2	1	Trial 2	At Morgantown 1 year, Kentucky 1 year
11	1923	Morgantown, W. Va.	1050	**N-grown**	**N-grown**	Hi-alt	1	2	3	Trial 7	At Morgantown 1 year, Minnesota 1 year
12	1923	Philippi, W. Va.	1550	Hi-alt	**Lo-alt**	Lo-alt	3	2	1	Trial 3	Two years at Morgantown
13	1923	Clifton Mills, W. Va.	1950	**Hi-alt**	**Lo-alt**	Hi-alt	3	1	2	Trial 3	Two years at Morgantown
14	1923	Duluth, Minn.**	1133	**N-grown**	**N-grown**	Hi-alt	1	2	3	Trial 3	Two years at Morgantown
15	1924	Morgantown, W. Va.	1050	**Hi-alt**	Lo-alt	Hi-alt	3	1	2	Trial 9	Three years at Morgantown
16	1924	Morgantown, W. Va.	1050	N-grown	N-grown	Hi-alt	1	2	3	Trial 14	Two years at Morgantown, 1 year at Minnesota
17	1924	Morgantown, W. Va.	1050	Hi-alt	N-grown	Hi-alt	2	1	3	Trial 8	Two years at Morgantown, 1 year at Kentucky

†Differences are significant in comparisons having bold-faced type.
*Southernmost.
**Northernmost.
‡Attention is directed to page 10.

A comparison of the northern-grown with the low-altitude strain shows the latter to have yielded most in nine of the sixteen trials. The yield differences were significantly better in six of these trials. In three of the seven trials remaining the northern-grown was conclusively superior.

Table 18 shows the high-altitude to have outyielded the low-altitude strain in eleven of the sixteen trials, but in only two are the differences significant. The low-altitude significantly outyielded the high-altitude strain in only one of the five remaining trials. In the comparison of the trials run in West Virginia the low-altitude strain ranked first in four instances and second in four. It ranked first in five and second in four when all the trials are included for consideration.

In only two of the sixteen trials was the northern-grown unquestionably superior to both West Virginia strains. The differences in all other trials favoring it were so slight as to have no significance.

Table 18 does not show conclusively that the place in which the seedlot is grown caused a change in the relationship of the strains in a definite direction. It is, however, of interest in that there seems to be a tendency for the high-altitude and northern-grown strains to yield highest at the highest altitude (1950 feet) in West Virginia and in Minnesota. This tendency is not as marked in respect to the low-altitude strain when grown at the lower altitudes of West Virginia (1050 to 1550 feet) and in Kentucky. It is also of note that the northern-grown strain from seedlots grown in Morgantown which were produced in Minnesota gave largest yields. The same is true with the low-altitude strain when produced the previous year in Kentucky.

DISCUSSION

The opinion is prevalent among growers that it is impracticable to attempt to produce potato seedstocks in this state which are reasonably comparable with those from the established sections of the North. With this in mind these experiments were designed to determine whether a recommended strain of seedstock from a northern seed-producing area would show outstanding characters when maintained for a series of years in plantings with highly selected native strains originated at the extreme altitudes in the state at which seedstocks would likely be grown (1050 to 3000 feet).

Yield only was taken as a criterion of value, since differences between the strains with respect to susceptibility to disease, insect injury, particular response to growing conditions, etc. would naturally be reflected in the yield. For this reason accepted practices of culture were employed. No attempts were made to take disease counts or to rogue or select within the plantings. On the contrary, a particular point was made to expose all the strains equally to the

same hazards as occur in the normal production of the commercial crop in the state.

There may also be some question on the part of the reader as to the justification of interpreting some of the results as contributing directly to proof that one strain was superior to another when the differences are shown to be insignificant.

The use of these data is here considered as being justified, in view of the general consistency of the results of these trials, in indicating that the native strains yielded most in West Virginia, even though the differences were not of mathematical significance in several instances. The data taken as a whole strongly indicate that there were differences in yielding capacity between the strains and that these differences persisted from year to year under the ordinary growing conditions of commercial crop production in this state.

SUMMARY

During the years 1921 to 1924, inclusive, 17 trials were carried on at four altitudes in West Virginia—from 1000 to 2000 feet—and at two latitudes outside the state—at the Kentucky and Minnesota Experiment Stations—in order to compare the performance, as measured by yield, of two native strains of Smooth Rural seed potatoes with a recommended strain of the same variety from the North, to determine primarily the feasibility of seed potato production in certain of the upland areas of this state. Observations were also made to ascertain to what degree, as shown by yield comparisons, changes of latitude were paralleled in effect on the strains by increase or decrease in altitude.

The native strains of seed potatoes had been maintained for a number of years at the high and low-altitude limits at which seed potatoes would likely be produced. The northern strain was produced in the extreme northern part of Minnesota.

The native strains (particularly the high-altitude strain) were superior to the northern-grown strain in the initial increase plantings at Morgantown in 1921. The differences in yield favoring these strains apparently persisted, since, with few exceptions, the native strains equaled or bettered the northern strain in yield in those trials carried on in West Virginia. The altitude at which the trials were run usually determined which of the native strains proved superior. Usually the high-altitude and northern-grown stocks gave higher yields at the higher altitudes, even as did the low-altitude strain in trials at the lower altitudes.

From the results of these trials it is apparent that the native strains compared favorably in performance with the northern strain; that these trials strongly indicate that the native strains did not deteriorate more rapidly than the northern strain. It is concluded therefore that it is feasible to produce seed potatoes in the medium altitudes of this state.

There appeared to be a tendency, although the data were meager and somewhat inconsistent, for the northern-grown and the high-altitude seed strains to yield more than the low-altitude strain in trials run in Minnesota and in the higher altitudes of West Virginia. Also, the low-altitude strain was usually superior in trials run at Kentucky and in the lower altitudes of West Virginia. This would suggest that an increase in altitude has an effect on the relative comparison of the strains similar to a change to a more northern latitude.

Since the northern-grown strain yielded more than the others in trials in West Virginia after a year in Minnesota, and the low-altitude strain acted similarly after a year in Kentucky, it would seem that the strains were not uniformly affected by the changed conditions: i. e., even a year's return of a strain to environmental conditions similar to those under which it was native caused an increase in vigor as here expressed by yields.

LITERATURE CITED

1. Bevan, W.
   1922. seed potatoes. Cyprus Ag. Jour. XVII: 36.
2. Jehle, R. A., and Oswald, E. I.
   1929. tests with potato seed from various sources. Md. Agr. Exp. Sta. Bul. 317.
3. Love, H. H.
   1924. a modification of student's tables for use in interpreting experimental results. Jour. Amer. Soc. Agron. XVI: No. 1, 68-73.
4. Love, H. H., and Brunson, A. M.
   1924. student's method for interpreting paired experiments. Jour. Amer. Soc. Agron. XVI: No. 1, 60-68.
5. Martin, W. H., Peacock, W. N., and Lombard, P. M.
   1925. northern versus southern grown seed. Proc. Potato Asso. Amer. XII: 23-32.
6. Schultz, E. S., and Folsom, D.
   1925. infection and dissemination experiments with degenerate diseases of potatoes. observations of 1923. Jour. Agr. Res. XXX: No. 6, 493-528.
7. Smith, A. G.
   1924. virginia mountain grown seed potato demonstrations. Proc. Amer. Soc. Hort. Sci.: 168-173.
8. Stuart, Wm.
   1913. place affect influence on seed potatoes. Vt. Agr. Exp. Sta. Bul. 172.
9. Wessels, P. H., and Hartwell, B. L.
   1927. viability and composition of "seed" potatoes as affected by climatic conditions and by various other factors. Jour. Am. Soc. Agron. XIX: No. 9.
10. Williams, C. B., and Mathews, C. D.
    1925. field crop experiments in north carolina. No. Car. Agr. Exp. Sta. Rept.

BULLETIN 243 SEPTEMBER, 1931

UNIVERSITY OF
JAN 0 1932

Soybean Culture and Varieties

BY M. M. HOOVER, T. C. McILVAINE, AND R. J. GARBER

Harvesting a Rod-row of Soybeans for Forage

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

Soybean Culture and Varieties

by M. M. HOOVER, T. C. McILVAINE, and R. J. GARBER

THE PURPOSE of this bulletin is to report the results of certain soybean investigations, to make recommendations in regard to varieties, and to give cultural directions for producing the crop under West Virginia conditions.

The soybean variety test has been carried on for ten years on the Agronomy farm of the Experiment Station at Morgantown and for a period of nine years at the Lakin Experiment farm in Mason County. It is felt that the results obtained from these variety tests are indicative of the relative yielding ability of the various varieties tested and should be of considerable aid to the farmer who is growing or considering the growing of soybeans.

COMMERCIAL IMPORTANCE

The soybean is an annual legume, native to southeastern Asia. The first introductions were made into the United States in 1804, but it is only within the last decade that this crop has become of much importance. Most of the acreage today is devoted to forage production. In certain localities, however, particularly within the cornbelt, seed production has proved profitable.

The acreage devoted to soybeans in the United States has shown a phenomenal increase since 1920. One hundred eighty-six thousand acres of soybeans were grown in the United States in 1921, with West Virginia reporting less than 1000 acres. In 1930 the acreage for the United States had increased to 3,500,000, while West Virginia reported more than 35,000. Such an increase in acreage for any one crop, in spite of the general curtailment of agricultural crop acreages within this state, indicates that the crop in question is contributing something of real value to those who grow it.

This increase in acreage is no doubt due in part to the fact that the soybean plant can be utilized in a number of ways. Some of the common uses follow:

HAY: Soybean hay of excellent quality can be made on most farms without the expenditure of money for new equipment and machinery. When fed to livestock, especially dairy cows, the hay is prized for its high protein content. There is a good demand for this legume hay and a grower rarely finds difficulty in disposing of surplus.

GREEN MANURE: Soybeans are vigorous growers and aid in building up the nitrogen and organic content of a soil. This is especially true when the plants are properly inoculated, since much of the nitrogen added to the soil when the tops and roots decay represents a gain from the atmosphere.

Crop Rotation: Many farmers who realize the value of a legume in the general rotation include soybeans in the cropping scheme. The short rotations into which the annual soybean crop can be fitted enable one to grow a legume crop more frequently on a given area than would be possible with crops of clover or alfalfa, which require two or more years.

Seed: In certain areas of the United States, especially in the cornbelt states, the production of soybean seed has been found to give profitable returns. At the present time much of the seed produced is used for planting, although the amount utilized in various industrial and manufacturing processes is increasing each year. These uses range from the production of oil cake for stock feed and oils for paints and varnishes to the many new preparations designed for human consumption.

LIME AND FERTILIZERS

Soybeans are more tolerant of acid soil than red clover, alfalfa, and many other agricultural crops. This fact has given rise to the feeling on the part of some growers that lime is not necessary for soybeans.

A rotation experiment in progress at the Lakin Experiment farm, where the yields of certain crops are compared on limed and unlimed series, shows five-year average yields of 23.1 and 17.4 bushels of seed and 1.12 and 0.98 tons of forage, respectively, for the limed and unlimed series. Although soybeans are tolerant of acid soil conditions the increase in yield of both seed and forage indicates a marked response to lime.

The West Virginia Station recommends 200 to 300 pounds of an 0-14-6 fertilizer for soybeans grown on sandy soil without manure and other legumes in the rotation. With silt or clay loam soil an application of 200 to 300 pounds of superphosphate alone is recommended. Nitrogenous fertilizers are unnecessary when the plants are properly inoculated, since the free nitrogen of the air is assimilated for use by the plant. On soils of low fertility a light application of a readily available nitrogenous fertilizer may be found advantageous in starting the crop.

SOIL AND CLIMATIC CONDITIONS

The climatic adaptations of the soybean are about the same as for corn. After the plants are well started they can withstand short periods of drought without serious injury, while a wet season does not seem to retard seriously the development of the crop. The period of germination is the most critical in the life of the plant, and excessive drought or moisture will prove most injurious at that time. Soybean plants are less susceptible to frost than cowpeas or corn.

Many of the most important varieties now being grown have been introduced from Asiatic countries. Some of these varieties have been found to fill certain climatic requirements. For this reason they are being grown in rather restricted areas.

The number of days required for maturity varies from 90 to nearly 200, while response to cultural treatment and soil fertility seems to show equally wide variation.

The soybean prefers a fertile loam or sandy loam but does well on any soil that will grow corn satisfactorily. Like other farm crops soybeans do best when planted in a well-prepared seedbed. In general the land should be prepared as for corn. A firm seedbed with a loose covering of fine soil is found to give most satisfactory stands. It is essential to have the surface free from clods, especially if the soybeans are seeded broadcast. If the seedbed has been thoroughly and carefully prepared it is often possible to follow the soybeans with the next crop in the rotation by disking the soybean stubble instead of plowing it under. This is especially true when such crops as wheat, rye, or alfalfa follow the soybeans.

INOCULATION

Soybeans, like other legumes, are able to utilize the free nitrogen of the air by the action of bacteria in the nodules on the roots of the plants. Many cases of success or failure in the growing of soybeans can be traced to the presence or absence of these bacteria.

Soybeans will make a satisfactory growth in a fertile soil in the absence of proper inoculation, but the nitrogen for growth is taken from the soil rather than from the free atmospheric nitrogen. If the fertility of the soil is low and available nitrogen is somewhat deficient, the leaves of uninoculated beans are pale yellow, whereas inoculated beans grown under similar conditions have a dark-green color and exhibit much more vigorous growth.

Natural inoculation will occur in a field for several years after the removal of inoculated soybeans. If the soil reaction is neutral or slightly alkaline, this time is greatly prolonged, but an acid soil seems to shorten considerably the period over which the bacteria remain active.

Two methods in general use for the inoculation of soybeans may be termed (1) the soil method and (2) the pure-culture method.

The soil method is probably the cheapest and easiest for the general grower. It can be carried out as follows: Obtain a sample of soil (a quart for each bushel of beans to be seeded) from one to three inches in depth from near the roots of soybean plants which are known to have been inoculated. This soil should be allowed to dry slowly, preferably in the shade, and sifted to remove the coarse soil particles. The soybeans should be dampened by sprinkling lightly with water, stirring until the seedcoats are moistened, and dusting with the fine screenings of inoculated soil. During the application of the water and soil the beans should be thoroughly stirred to make certain that each seed receives a film of water and a coating of dust. The seed may be planted immediately or, if necessary, permitted to dry somewhat before being seeded.

The method just described is commonly spoken of as the dry-soil inoculation. A variation of this procedure known as the wet-soil

method differs in that a thin muddy paste is first made from the inoculated soil. The seed is dipped into this muddy water, allowed to dry, and seeded. This method seems to give no better inoculation and involves considerably more time and work, since the wet beans must be stirred while drying, or difficulty will be encountered from the germinating beans.

A third variation of the soil inoculation method is similar to the dry method first described, except that the beans are not moistened, and more soil is used. Approximately one peck of soil for each bushel of beans is obtained, pulverized, and placed in the drill box on top of the beans. The inoculated soil and beans are drilled together.

The pure-culture method consists of inoculating the soybean seed with a pure culture of the bacteria which produce the root nodules. Nearly all commercial seed houses are equipped to supply sufficient pure cultures of bacteria for the amount of seed purchased. Directions for use of the pure culture inoculum are sent with the container.

TIME AND METHOD OF SEEDING

Soybeans are usually planted just after corn-planting time. This will insure warm soil and if the seedbed has been thoroughly prepared and is free from weeds, one may expect a good stand. West Virginia Bulletin 227 reports data obtained when soybeans were planted at approximately 15-day intervals from May 5 to July 10. The average yield over a 3-year period was slightly in favor of the early plantings, but the corresponding hay was coarse and weedy. On the other hand the hay produced from the late plantings was not only low in yield but also difficult to cure into a satisfactory feed. The results indicate that the optimum time to plant is between May 15 and June 15 for West Virginia conditions. These findings at West Virginia are in general agreement with reports from other experiment stations located in the same general latitude.*

The method of seeding may differ somewhat, depending upon the use to be made of the crop. If soybeans are to be grown for seed the common practice is to plant them in rows of sufficient width to permit cultivation. These may vary from 28 to 42 inches. The most suitable width seems to depend upon the implements available for cultivation and culture of the plants. Some growers find that by closing certain of the openings, an ordinary grain drill can readily be converted into a bean drill which will give rows of any desired width. If the larger openings are used there is less danger from splitting the beans. Corn planters may be used for seeding the beans alone or in mixtures with corn. If corn and soybeans are seeded together the

*Iowa Bulletin 228 reports May 24 and May 10 as the optimum dates for seed and forage yield, respectively. Virginia Bulletin 235 gives May 11 as the optimum date for planting beans for hay or forage. Ohio Bulletin 384 reports May 19 and June 12 as the best dates for seed and forage, respectively. The Missouri Station reports June 1 to June 15 as giving best yields under their conditions.

seed mixture should be stirred frequently for uniform distribution. As a general rule the stand of both crops is not as uniform when they are seeded together as when they are drilled separately.

When soybeans are grown for hay or green manure the most satisfactory method of seeding is in close drills, although broadcast seeding gives satisfactory yields and is practiced rather generally throughout the cornbelt states. The rate of seeding depends somewhat upon the variety of soybeans grown and the use to be made of the crop. West Virginia Bulletin 227 gives the data obtained during the years 1921-25, inclusive, when beans were drilled at the rate of 4, 5, 6, and 8 pecks per acre. The conclusion drawn is that with varieties with medium-sized seed such as Wilson, the best rate of seeding is 6 to 8 pecks per acre. The fine quality of hay with few weeds, along with a slightly higher tonnage, indicates this rate as the most desirable. When planted in rows and grown as a cultivated crop there seems to be no distinct advantage in heavy seeding. Yields reported by the Indiana, Iowa, Ohio, and Virginia Stations show no significant increases in yield of seed with rates of seeding varying from fifteen to thirty pounds per acre.

The Iowa and Virginia Stations have reported yields of hay from plots receiving various types of cultivation. The conclusions drawn point to a distinct advantage in favor of cultivation; this is not only indicated in yield but also in freedom from weeds. It is the practice at the West Virginia Station to cultivate the solid drilled plots with a spike-tooth harrow. The teeth should be slanted backward considerably to prevent injury to the seedlings. One should not cultivate the plants just as they are emerging because of the severe injury that may result. Cultivation should follow the drill row and may be continued until the seedlings are several inches high. It is found that such treatment is very effective in the control of grass and weeds.

SOYBEAN HAY MIXTURES

Soybeans make a very desirable hay mixture when seeded with 6 to 8 pounds of Sudan grass per acre. This combination has been recommended by the Iowa Station and has also proved to be the most desirable of four combinations grown at the West Virginia Station.

The Sudan grass—soybean mixture gives a hay of good quality and desirable yield and has the important advantage of ease of curing.

When grown for hay soybeans should be cut when the pods are well filled but before the leaves turn yellow and fall. Some growers prefer cutting when the seed in the pod is just beginning to form. Varieties differ greatly in their fineness of stem and ability to retain leaves. The most desirable hay types become woody if allowed to stand too long.

When cut for hay the plants should remain in the swath until well wilted. The curing process should then be completed in small cocks or windrows. If the hay has become too dry in the swath it

should be raked after a heavy dew to prevent excessive loss of leaves. During unfavorable weather conditions the curing process takes considerable time, but a good quality hay can be made by permitting the complete curing in small cocks. Wet or uncured soybean hay should not be stacked or put into the mow because of the danger of spoiling.

It has been the practice for some years on the Agronomy farm to establish alfalfa meadows after the removal of a soybean hay crop. If the seedbed is well prepared in the spring for soybeans the alfalfa can successfully be established by thoroughly disking the soybean stubble and seeding the alfalfa between August 1 and 15. When this practice is followed, 400 to 500 pounds of a mixed fertilizer carrying some nitrogen such as a 2-14-4 should be applied to the seedbed for alfalfa. By following this procedure one can get considerable cash return from the land and at the same time establish the alfalfa meadow under optimum conditions.

When soybeans are grown for seed the plants should be permitted to stand until the pods are ripe, but harvested before excessive loss from shattering has occurred. As a general rule the leaves will all be off before the seed is ripe. A grain binder makes a very satisfactory implement for harvesting the beans for seed. If the beans have been grown in rows the binder can handle two rows at a time. The cutting should be done while the plants are damp and tough in order to reduce shattering to a minimum. The beans should be placed in small shocks, and threshed when properly cured. Care in threshing should be exercised in order to prevent loss from cracked and broken beans. The removal of concaves with a greatly reduced cylinder speed will generally give good results with most threshers.

Beans should be thoroughly dry before being stored in large bulk since seed that is allowed to heat soon loses its viability and is of no value for seeding purposes.

The foregoing account is given in order to acquaint the prospective grower with the salient facts regarding the culture of this crop. The following section will introduce the experimental data upon which the choice of a variety should be made.

METHODS USED IN EXPERIMENTS

The experimental area on the Agronomy farm at Morgantown was treated with an application of superphosphate at the rate of 200 pounds per acre per year. Lime was applied as needed to maintain a favorable reaction for plant growth. The soybeans were not grown on the same area each year but appeared in their proper sequence in a more or less regular rotation which covered most of the tillable area of the Agronomy farm. The plots consisted of two rows, 18 feet long and 30 inches apart. During the first three years of this experiment the plots consisted of four rows, data being recorded only on the yields obtained from the center rows of the plots. It was felt that the two border rows were necessary in order to eliminate

border influence of adjacent varieties. As the result of a careful study made on the influence of adjacent rows of soybeans on one another,* it was found that the border influence of adjacent rows was negligible. Therefore the plot size was reduced to two rows in the later trials.

Each variety was grown in five plots systematically distributed over the experimental area and seeded by hand. The seeds were spaced approximately one inch apart in the row. The weight of seed per row was determined as the result of a germination test made on all varieties prior to seeding. At harvest the rows were reduced to 16 feet. When harvested for hay the green weight of one row of a variety was recorded. A weighed sample of the green material was taken from each harvested row and dried to determine the air-dry weight. The second row of each plot was permitted to stand until ripe; this was cut, placed in a burlap bag until thoroughly dry, and threshed on a small rod-row thresher. The seed obtained was then cleaned, weighed, and calculated on the basis of acre yield. General notes of agronomic interest such as height, coarseness of stem, days to mature, retention of leaves, and character of growth were recorded for each of the varieties in the experiment.

The experiments at Lakin were similar to those at Morgantown except for the year 1922, when the plots consisted of two rows approximately 40 feet in length.

EXPERIMENTS AT THE AGRONOMY FARM

Thirty-five varieties and pure-line selections of soybeans were included in the varietal experiments on the Agronomy farm. Nineteen of these varieties were grown for the ten-year period from 1921 to 1930, inclusive, while 16 varieties were grown for the six years from 1925 to 1930. All varieties were tested from the standpoint of both seed and forage yields.

The varieties listed in Table 1 are arranged according to rank as determined by their average yields. Column 2 shows the average number of days required to mature seed. It will be noted that these varieties can be arranged conviently into early, medium, and late groups. U. S. No. 36902, Manchu, Black Eyebrow, and Elton constitute the early varieties and require less than 130 days to mature seed. These four varieties rank second, fourth, thirteenth, and eighteenth in yield. The medium group requires between 130 and 145 days to mature seed and includes most of the varieties of this test. The late varieties require from 145 to 155 days to mature seed and include Mikado, Morse, Dixie, Lexington, Austin, Hahto, and Mammoth Yellow. Some of these varieties fail to produce a normal seed crop during certain seasons.

There seems to be no direct relation between the average number of days to mature seed and yield in the varieties compared. Haberlandt, a relatively late variety, ranks first, followed by U. S. No. 36902, an early variety. In general the late maturing sorts tend to

*Jour. Amer. Soc. Agron. Vol. 18, No. 7.

TABLE 1.—*Yield in bushels per acre and days to mature of soybean varieties grown on the Agronomy farm*

Variety	West Virginia No.	Ave. No of Days to Maturity	Yield in bushels per acre										Ave. 1921-1930	Ave. 1925-1930
			1921	1922	1923	1924	1925	1926	1927	1928	1929	1930		
Haberlandt	5	145.6	36.9	20.2	34.2	26.7	23.3	36.8	19.4	31.8	30.6	15.1	27.5	26.2
U. S. No. 36902	26	127.5	36.6	26.5	36.3	25.5	23.8	30.3	16.5	32.9	24.4	18.6	27.1	24.4
U. S. No. 30745	24	136.3	36.6	24.3	27.8	26.1	23.6	31.5	18.6	38.0	25.0	15.9	26.8	25.5
Manchu	4	127.9	28.9	22.3	28.5	27.6	30.5	28.0	14.5	33.4	27.9	18.4	26.0	25.5
Wilson	9	132.3	28.8	24.0	27.2	25.5	22.3	28.5	19.9	34.8	27.5	18.6	25.7	25.3
Ohio 9016	18	133.0	29.1	23.2	30.1	19.7	23.5	37.2	16.4	36.8	26.6	14.0	25.7	25.7
Hamilton	19	140.9	30.5	23.1	34.9	22.6	21.1	34.7	14.7	32.3	29.3	13.2	25.7	24.2
Wilson (Check)	1	132.4	31.7	22.6	29.9	25.6	23.1	28.3	17.6	32.9	25.9	16.6	25.4	24.1
Peking Sel. I-21-8	16	135.3	36.8	20.5	24.2	22.9	20.8	29.2	18.1	31.1	30.7	18.5	25.3	24.7
Peking Sel. I-21-7	15	135.8	37.8	20.3	25.3	20.3	21.3	28.3	17.3	32.7	27.6	18.0	24.9	24.2
Wilson Sel. I-21-9	17	134.5	35.0	21.9	21.7	23.9	22.4	28.5	16.9	32.0	27.5	17.1	24.7	24.1
Virginia	10	141.5	34.9	21.0	23.2	23.1	21.4	27.8	19.9	28.2	27.9	15.9	24.3	23.5
Black Eyebrow	3	128.8	28.1	22.6	21.9	22.3	26.9	25.9	16.3	31.5	22.9	16.7	23.5	23.4
Medium Green	8	130.9	31.9	20.9	25.2	22.3	20.3	31.1	13.5	33.5	19.7	13.0	23.1	21.9
Peking Sel. I-21-5	14	135.6	33.8	17.8	22.5	18.4	20.2	26.7	17.1	29.1	28.5	17.2	23.1	23.1
Aksarben	23	137.4	26.9	18.9	32.4	24.5	21.2	30.2	15.1	24.3	21.7	16.6	23.2	21.5
Mikado	7	150.2	29.2	22.5	25.3	24.0	16.1	31.5	18.4	22.3	20.1	10.1	22.0	19.8
Elton	2	126.7	30.3	24.4	25.3	22.9	22.8	21.1	10.4	27.6	17.3	12.2	21.4	18.6
Peking	11	144.2	31.4	15.9	20.6	17.6	17.0	25.2	17.0	24.3	20.6	12.4	20.2	19.4
Morse	31	148.9	...	...	...	...	20.7	33.9	18.9	29.1	22.0	15.1	...	23.3
Hoosier	44	138.5	...	...	...	...	21.5	26.3	16.0	31.7	25.6	16.1	...	22.9
Dixie	46	150.2	...	...	...	...	19.3	26.7	19.1	32.8	25.2	11.8	...	22.5
Merko	38	140.3	...	...	...	...	22.6	26.7	18.1	28.5	21.8	14.2	...	22.0
Ebony	40	135.6	...	...	...	...	21.2	27.1	16.0	29.1	19.3	12.1	...	20.8
Lexington	39	151.1	...	...	...	...	18.0	30.0	17.0	22.5	19.3	13.5	...	20.1
Austin	34	152.5	...	...	...	...	17.0	27.3	17.4	23.1	21.7	12.6	...	19.9
Hollybrook	29	141.8	...	...	...	...	20.3	29.7	9.6	26.3	16.5	10.5	...	18.8
Wilson-five	33	138.3	...	...	...	...	17.8	24.1	14.7	22.9	19.3	13.6	...	18.7
Columbia	43	142.5	...	...	...	...	16.5	27.1	12.8	20.7	19.7	13.8	...	18.4
Midwest	37	146.1	...	...	...	...	20.0	25.9	11.6	24.3	17.8	10.6	...	18.4
Hahto	42	156.7	...	...	...	...	12.5	27.0	15.7	22.5	20.0	8.8	...	17.8
Chiquita	41	153.1	...	...	...	...	13.5	36.0	12.6	15.7	15.2	10.8	...	17.3
Haberlandt 38	36	151.0	...	...	...	...	10.5	34.4	10.4	21.5	13.0	9.0	...	16.5
Laredo	45	154.3	...	...	...	...	14.5	26.6	15.2	14.9	14.1	7.0	...	15.4
Mammoth	30	156.1	...	...	...	...	3.9	19.0	6.3	4.4	3.7	Failure		7.5

give the lowest yields. This is particularly evident when the data obtained from 1925-1930 are considered.

Columns 13 and 14 of Table 1 give the average yields in bushels of seed per acre for the 19 varieties grown from 1921-1930 and for all varieties for the years 1925-1930, respectively.

The extreme difference in average yield between any two varieties grown for the 10-year period is 7.3 bushels. When the average annual yields of Haberlandt and Peking are paired according to Student's method of calculating paired yields, it is found that extremely high odds (9999:1) in favor of Haberlandt are obtained. These odds are significant and are interpreted to mean that the difference in yield obtained in this experiment is due to a real difference in the yielding capacity of these two varieties and not to chance.

Haberlandt ranks first in yield of seed per acre with an average of 27.5 bushels. This is but slightly better than U. S. No. 36902, which has an average yield of 27.1 bushels. The difference of 0.4 bushel is not a significant difference.

Wilson, which was used as a check throughout this experiment, ranks eighth with an average yield of 25.4 bushels of seed per acre. This is 2.1 bushels less than Haberlandt and represents odds of 20:1 in favor of Haberlandt when calculated according to Student's method. The difference in capacity to yield between Haberlandt and Wilson varieties would probably not be considered a significant one since odds of approximately 30:1 are the generally accepted criteria of significance.

Most of the varieties that were grown only for the 6-year period are late-maturing sorts and this is reflected in the average yield of seed. The order of ranking of all varieties is changed but slightly when the 6-year average is compared with the 10-year average.

Table 2 contains data for yield in tons of air-dry hay per acre, as well as height and days to mature hay for the soybean varieties grown at Morgantown.

Column 2 shows that the average height of the varieties varies from 29.6 inches for Elton to 51.9 inches for Virginia. The taller varieties tend to show higher average yields of forage than the early, shorter varieties.

Column 3 shows the average number of days to mature hay. Elton is the earliest variety grown in the experiment, maturing hay in 87 days, while Chiquita and Peking were the latest maturing varieties in the 10-year and 6-year groups, maturing hay in 118 and 110 days, respectively. It is interesting to note that the varieties which give the heaviest forage yields are those which utilize the full period for growth and are thus considered relatively late types.

Columns 14 and 15 give the average yield in tons of air-dry hay per acre for the years 1921-1930 and 1925-1930, respectively.

Haberlandt with an average yield of 2.36 tons of air-dry hay per acre ranks first and averages about ¼ ton more than Peking, which ranks second with an average of 2.12 tons per acre. This difference is fairly consistent over the period of the experiment. Haberlandt

TABLE 2.—*Yield in tons of air-dry hay per acre, with height and days to mature, for hay of soybean varieties grown on the Agronomy farm*

Variety	West Virginia No.	Average Height in Inches	Ave. No. of Days to Mature Hay	Yield in tons of air-dry hay per acre										Ave. 1921-1930	Ave. 1925-1930
				1921	1922	1923	1924	1925	1926	1927	1928	1929	1930		
Haberlandt ...	5	37.1	105.3	2.53	2.58	2.22	3.06	2.69	2.41	1.74	2.63	2.15	1.63	2.36	2.21
Peking	11	44.1	110.0	2.42	2.24	2.42	2.10	1.93	2.20	1.48	2.50	2.17	1.72	2.12	2.00
Peking S. I-21-8	16	41.7	105.2	2.90	2.40	2.16	2.08	2.27	1.89	1.38	2.15	2.37	1.53	2.11	1.93
Mikado	7	35.9	108.1	2.25	2.05	2.12	2.10	1.97	2.49	1.54	2.49	2.37	1.57	2.10	2.07
Peking S. I-21-7	15	42.7	104.5	2.82	2.16	2.49	2.01	2.33	1.75	1.49	2.20	1.99	1.57	2.08	1.89
Peking S. I-21-5	14	42.4	105.0	2.73	2.40	2.28	2.09	2.21	1.80	1.30	2.16	2.26	1.48	2.07	1.91
Aksarben	23	33.1	101.9	2.16	2.06	2.09	1.96	2.20	2.62	1.50	2.06	2.17	1.67	2.05	2.04
Hamilton	19	32.6	102.6	2.13	2.06	2.33	2.21	2.21	2.44	1.31	2.15	1.98	1.37	2.02	1.91
Virginia	10	51.6	105.7	2.57	2.41	2.38	2.03	2.09	1.61	1.35	1.93	2.25	1.49	2.01	1.79
Wilson 89	1	39.9	100.1	2.30	1.99	2.31	2.13	2.02	1.73	1.29	1.98	2.56	1.54	1.99	1.85
Wilson I-21-9..	17	41.7	103.0	...	2.17	2.26	2.09	2.42	1.52	1.36	2.09	2.24	1.60	1.97	1.87
Wilson	9	38.8	100.2	2.39	2.46	2.17	2.01	2.10	1.67	1.39	1.99	1.98	1.42	1.96	1.76
Ohio 9016	18	29.7	100.2	2.31	1.97	2.07	2.09	2.14	1.97	1.26	1.90	1.89	1.61	1.92	1.79
Medium Green.	8	32.9	99.9	2.26	2.39	2.27	2.18	2.16	1.69	1.12	2.04	1.58	1.40	1.91	1.67
U. S. No. 36902.	26	31.1	91.9	2.42	2.02	2.03	1.77	2.10	1.69	1.10	1.77	1.50	1.43	1.78	1.60
U. S. No. 30745.	24	34.8	94.7	2.27	2.07	1.99	1.92	2.08	1.71	1.23	1.70	1.73	1.30	1.80	1.62
Manchu	4	34.2	88.0	2.13	2.02	1.94	1.84	1.86	1.62	1.14	1.84	1.67	1.54	1.76	1.61
Black Eyebrow	3	32.5	88.2	1.69	2.11	1.77	2.00	1.74	1.57	1.04	1.72	1.53	1.57	1.67	1.53
Elton	2	29.6	87.0	2.03	1.77	1.94	1.84	1.49	1.64	.68	1.57	1.23	1.21	1.54	1.30
Haberlandt 38 .	36	38.5	116.2	...	...	...	...	2.74	2.79	2.19	2.39	2.62	1.57	...	2.38
Laredo	45	40.7	123.0	...	...	...	...	2.37	2.66	1.69	2.29	2.68	1.58	...	2.21
Dixie	46	36.7	109.2	...	...	...	...	2.33	2.11	1.98	2.75	2.58	1.43	...	2.20
Chiquita	41	44.2	118.1	...	...	...	...	2.32	2.71	1.42	2.48	2.62	1.56	...	2.19
Morse	31	35.2	109.6	...	...	...	...	2.29	2.54	1.61	2.21	2.29	1.64	...	2.10
Lexington	39	33.9	112.2	...	...	...	...	2.28	2.63	1.58	2.42	1.92	1.61	...	2.07
Austin	34	34.3	109.6	...	...	...	...	2.02	2.24	1.71	2.21	2.16	1.65	...	2.00
Merko	38	36.3	103.3	...	...	...	...	2.37	1.78	1.47	2.48	2.06	1.40	...	1.93
Columbia	43	37.7	111.2	...	...	...	...	2.17	2.28	1.40	1.89	1.98	1.57	...	1.88
Mammoth	30	35.3	114.6	...	...	...	...	2.18	2.24	1.24	2.12	1.88	1.19	...	1.81
Hahto	42	29.3	116.0	...	...	...	...	1.39	2.36	1.58	2.55	2.05	1.21	...	1.86
Wilson-five ...	33	42.1	105.8	...	...	...	...	2.10	1.94	1.41	1.94	1.79	1.41	...	1.76
Hollybrook ...	29	33.6	105.0	...	...	...	...	2.07	1.64	1.03	2.05	1.65	1.11	...	1.59
Hoosier	44	30.7	92.3	...	...	...	...	1.85	1.62	1.23	2.75	1.60	1.38	...	1.74
Ebony	40	29.9	104.7	...	...	...	...	2.08	1.71	1.31	2.08	1.76	1.44	...	1.72
Midwest	37	30.0	104.8	...	...	...	...	1.93	1.75	1.10	2.06	1.53	1.12	...	1.58

produced more hay than Peking in seven of the ten years. In the three years in which Peking outyielded Haberlandt the differences in favor of Peking were small. Due to the fact that the differences in most years are in favor of Haberlandt, calculations by Student's method of pairing annual average yields give odds of 30:1. This 0.24 ton difference in yield between Haberlandt and Peking is a real difference in capacity to yield and is not due to chance fluctuations.

Wilson checks rank tenth in yield of air-dry hay per acre with an average annual yield of 1.99 tons. This represents an average annual yield of 0.37 tons less than Haberlandt. The calculated odds indicating this to be a real difference in yielding capacity of the two varieties are about 95:1 in favor of Haberlandt.

It is of interest to note that Haberlandt ranks first both in respect to seed and forage yields. Most of the soybean acreage grown in West Virginia is used for forage; therefore the matter of forage yield is very important to the grower in this state. Gross yield, however, should not be the only consideration, for the quality of the hay as reflected in coarseness of stalks and relative amounts of leaves is important from the standpoint of the grower.

Data recorded in column 15 of Table 2 give the average yields of all varieties between the years 1925-1930, inclusive. The yields range from 2.38 to 1.30 tons of air-dry hay per acre. These yields for the most part represent small differences for the varieties contained in the experiment. Unlike the yields for seed per acre given in Table 1, where the late maturing types were low in yield, Table 2 shows that the varieties giving greatest forage yields are those which utilize all of the growing period and thus come in the late-maturing group.

EXPERIMENTS AT THE LAKIN EXPERIMENT FARM

The experimental work at Lakin consisted of a comparative study of yields of forage and seed of certain varieties when grown in plots of cultivated rows and solid drill rows. In addition, eleven soybean varieties were grown at the Lakin Experiment farm during the years 1922-1929, while six of these varieties were grown from 1922-1930, inclusive. Plot size, arrangement, and method of obtaining yields at Lakin were similar to the methods used at the Agronomy farm at Morgantown, as previously described.

The varieties grown and the yield of seed in bushels per acre are listed in Table 3. The varieties are arranged according to their average yield in bushels per acre for the 8-year period for which comparable data are available. Hamilton ranks first with an average yield of 34.4 bushels of seed per acre, while Royal ranks lowest with an average yield of 26.6 bushels per acre. This difference in yield of 7.8 bushels represents a real difference in the yielding capacity of these two varieties.

Table 4 lists the varieties of soybeans grown at the Lakin Experiment farm in the order of their yield of air-dry hay in tons per

acre. Sherwood ranks first, Virginia second, and Haberlandt third with yields of 2.94, 2.91, and 2.89 tons, respectively.

It is of interest to note that the varieties that gave low yield of seed per acre are among the high producers of forage. Sherwood and Royal, tenth and eleventh in seed production, rank first and fourth, respectively, in yield of air-dry hay per acre.

Haberlandt, first in both seed and hay production at Morgantown, again demonstrated its capacity to yield when it ranked third in seed and forage yields at Lakin.

TABLE 3.—*Yield in bushels per acre of soybean varieties grown at the Lakin Experiment farm*

Variety	Yield in bushels per acre									Ave. 1922-1929	Ave. 1922-1930
	1922	1923	1924	1925	1926	1927	1928	1929	1930		
Ohio 9035 (Hamilton)	41.6	36.8	33.4	32.2	36.6	27.6	35.7	31.1	...	34.4	...
S. P. I. 36902	38.6	38.3	33.3	29.6	30.0	33.0	39.6	33.7	...	34.5	...
Haberlandt	38.2	35.4	30.2	31.9	32.2	30.3	36.6	31.2	29.1	33.2	32.8
Hollybrook	35.5	36.3	27.1	31.1	31.5	26.3	27.7	27.2	28.8	30.3	30.2
Peking I-21-7	31.5	36.1	28.5	27.2	31.0	26.9	38.5	32.5	28.3	31.5	31.2
Check (Wilson 89)	33.0	33.2	27.9	30.1	30.1	29.5	34.9	33.5	31.8	31.5	31.6
Virginia	33.1	31.7	28.1	30.4	30.5	26.7	32.2	31.4	29.3	30.5	30.4
Peking I-21-8	31.1	31.7	28.2	25.1	28.8	25.6	38.4	31.8	31.3	30.1	30.2
Md. No. 19186-B	26.2	28.7	27.8	31.1	29.7	26.6	29.5	32.7	...	29.0	...
Sherwood	27.9	26.0	24.7	29.6	28.6	20.3	31.4	30.7	...	27.4	...
Royal	26.6	19.3	22.7	28.8	26.5	25.4	31.2	32.3	...	26.6	...
Manchu	...	...	...	...	33.0	32.8	37.2	31.7	35.6	34.1	...
Midwest	...	...	...	...	29.5	20.9	30.5	27.7	24.3	26.6	...

TABLE 4.—*Yield in tons of air-dry hay per acre of soybean varieties grown at the Lakin Experiment farm*

Variety	Yield in tons of air-dry hay per acre									Ave. 1922-1929	Ave. 1922-1930
	1922	1923	1924	1925	1926	1927	1928	1929	1930		
Sherwood	2.80	2.87	3.14	2.78	2.82	2.57	3.59	2.92	...	2.94	...
Virginia	3.47	2.70	3.14	2.55	2.91	2.29	3.09	3.11	2.70	2.91	2.88
Haberlandt	2.82	2.75	3.10	2.91	3.15	2.42	3.23	2.76	2.78	2.89	2.88
Royal	2.98	2.73	2.99	2.45	2.57	2.38	3.24	2.65	...	2.75	...
Peking I-21-7	3.06	2.42	2.67	2.52	2.51	2.22	3.33	2.92	2.66	2.71	2.70
Hamilton	2.96	2.39	2.85	2.36	2.77	2.34	3.36	2.68	...	2.71	...
Md. No. 19186-B	2.90	2.96	2.86	2.48	2.63	2.02	2.93	2.66	...	2.68	...
Peking I-21-8	2.74	2.26	2.54	2.67	2.59	2.22	3.20	2.93	2.77	2.64	2.66
S. P. I. 36902	2.91	2.24	2.52	2.49	2.55	2.53	2.92	2.63	...	2.60	...
Check (Wilson 89)	2.74	2.33	2.64	2.28	2.39	2.07	3.18	2.83	2.71	2.56	2.57
Hollybrook	2.69	2.32	2.49	2.16	2.45	2.23	2.87	2.53	2.63	2.47	2.49
Manchu	...	...	...	...	2.32	2.29	2.99	2.49	2.66	2.55	...
Midwest	...	...	...	...	2.15	2.06	3.11	2.52	2.20	2.41	...
Mammoth Yellow	...	...	...	...	2.72	...	...	2.60	2.33	2.55	...

YIELD IN CULTIVATED ROWS AND SOLID DRILL ROWS

Bulletin *227* of the West Virginia Station gives the forage yields of Wilson soybeans obtained at Morgantown when grown in cultivated and solid drill rows. No significant difference was observed for the 5-year period during which this experiment was conducted.

The experiments at Lakin on the yield of cultivated and solid drill plots have been more extensive than the work at Morgantown. Three varieties of soybeans, Virginia, Peking Selection I-21-7, and Elton were compared for yield of forage over a 5-year period and compared for yie'd of seed for two years. Wilson variety was also included in the comparison for yield of seed.

The cultivated plots consisted of three rows, 30 inches apart and approximately 25 feet in length. Seeds were spaced approximately 1½ inches apart along the rows. About 1¾ feet were discarded from the end of the plot and the remainder of the center row was used in obtaining yields.

The solid drill plots were approximately 10½ feet x 25 feet gross and 8⅙ x 21½ feet net after removing the borders. The rate of seeding was 6 pecks per acre.

Both the solid drill plots and the cultivated row plots were planted in quadruplicate each year except in 1923, when there were eight cultivated row plots. In this year a solid drill plot occurred between each pair of cultivated row plots of the same variety. During the other years of the test the cultivated row plots were alternated with the solid drill plots of the same variety; or by another arrangement they were placed in close proximity to one another.

Table 5 gives the yield of air-dry hay in tons per acre for the three varieties during the period of this experiment. Yield differences, while not great, are fairly consistent in favor of the drill plots. When these differences are studied according to Student's method, odds are obtained in favor of solid drill over cultivated rows of 15:1, 10:1, and 38:1 for Peking Selection I-21-7, Virginia, and Elton varieties, respectively.

TABLE 5.—*Yield in tons per acre of air-dry hay of soybeans when grown in drill vs. row plats at the Lakin Experiment farm*

Year	Peking I-21-7		Virginia		Elton	
	Drill	Row	Drill	Row	Drill	Row
1923	2.79	2.52	3.18	2.74	2.24	2.07
1924	3.01	2.79	2.87	3.10	2.62	2.49
1925	2.29	2.43	2.69	2.47	2.20	2.14
1926	2.74	2.58	2.94	2.82	2.73	2.51
1930	3.13	2.59	2.99	2.53	2.79	2.60

TABLE 6.—*Yield in bushels of seed produced by solid drill and cultivated row plats for the year* 1927-1928

Year	Peking Sel. I-21-7		Virginia		Elton		Wilson	
	Drill	Row	Drill	Row	Drill	Row	Drill	Row
1927	29.4	28.3	32.0	27.9	31.4	29.7	26.9	27.2
1928	33.1	35.2	29.7	31.1	14.8	15.9	28.1	32.5

If the combined data for the three varieties are studied, the odds obtained are 458:1 in favor of solid drill over the cultivated row method of seeding. These differences although small are consistent and are fairly significant for the varieties studied in this manner. When P values are determined by the use of Fisher's application of Student's method, the odds are found to agree very closely with those given above.

Table 6 gives the data obtained in yield of seed produced by solid drill and cultivated row plots for the years 1927-1928. It is of

interest to note that the yields obtained during 1927 show a decided advantage in favor of the solid drill plots, while the data for 1928 indicate an equally favorable yield for the cultivated row plots. This would seem to indicate that seasonal differences exert considerable influence on yield of seed. Since the available data cover but a two-year period, it is obvious that further investigations are necessary to obtain trustworthy data.

From a study of the data presented in this bulletin several facts are observed which may be used in guiding one in the choice of variety.

(1) The data indicate that soybean varieties may be divided into seed and forage groups. It is rather uncommon to find a single variety that will excel in yield in both seed and forage.

(2) The choice of variety should be controlled by the use to be made of the crop, whether for seed or hay.

(3) If the crop is to be grown for seed, a variety that will consistently mature within the frost-free growing period should be chosen.

(4) If the crop is to be grown for hay, one should choose a variety which will give a high yield of a fine-stemmed, leafy forage, and one the seed of which is easily available on the market.

(5) Haberlandt has demonstrated its ability to yield both seed and hay under the conditions of this experiment. Although gross yield of forage is satisfactory, the quality of hay is very poor since the plants are coarse and stemmy.

(6) Most growers prefer varieties that will give a good yield of fine-quality hay and a fair seed yield. Such varieties as Peking Selection I-21-7, Wilson, or Peking may serve as a general purpose type better than the higher-yielding Haberlandt. One of the chief reasons for the popularity of the Wilson variety in this state is the dependability of the crop in producing a good-quality hay and a fair seed yield. The availability of Wilson seed in commercial amounts is another factor that should have considerable influence in the choice of this variety.

DESCRIPTION OF VARIETIES

A description of the varieties which produced high average yields of hay and seed in the experiments may be of interest and aid to the grower in choosing the proper variety.

HABERLANDT: A late variety requiring 105 days to reach the proper stage for hay and approximately 145 days to mature seed. The plants are stout, erect, bushy, with medium-sized leaves that are somewhat leathery in texture. The stems are covered with a tawny pubescence. Flower color may be either purple or white. Seeds are rather large, straw colored, with a dark-brown hilum.

PEKING: This variety is an erect, fine-stemmed type requiring 110 days to reach the proper stage for hay and 144 days to mature seed. Plants have a tawny pubescence, with fine stems and abundant leaves. Flower color may be either purple or white. Seeds are

medium in size, somewhat flattened, with black glossy seedcoat. This variety is widely grown for its desirable hay yields.

Wilson: This variety is erect, bushy, and fine-stemmed. In growth habit it is very much like Peking but under West Virginia conditions it will mature hay and seed about ten days to two weeks earlier than Peking. The seed is black and somewhat larger and fuller than Peking. Wilson is the most popular and widely grown soybean variety in West Virginia. Seed is readily available in commercial quantities and the yields of seed and hay are satisfactory and dependable.

Peking Selection I-21-7: This pure-line selection was made at the West Virginia Station from the Peking variety. In yield of seed and forage it is very similar to Wilson but differs from Wilson in that the leaves are maintained until the plants are ready to harvest for seed.

Hamilton: This is a stout, erect, bushy type of soybean which matures hay in 102 days and seed in approximately 140 days. Hamilton was introduced by the Ohio Station. The plants have a tawny pubescence, purple flowers, and large brown seeds with brown hilum. Hamilton produces rather coarse forage but has given satisfactory yields of seed and hay at Morgantown and at the Lakin farm.

Sherwood: A late-maturing variety with fine stems and many leaves. The plants have a gray pubescence with white flowers and yellow seed. This variety has given the best average yield of hay of all varieties tested at Lakin.

Virginia: A late-maturing variety which requires 105 and 141 days to mature hay and seed, respectively. This is a very fine-stemmed variety with a tendency to vine. Hay is fine and generally of very good quality. The plants are covered with a tawny pubescence and produce purple flowers. Seeds are medium in size, flat, and brown in color. This variety is widely grown in certain regions of the United States and finds favor with many growers, particularly when grown with corn. Virginia has never given exceptional yields under West Virginia conditions.

SUMMARY

Thirty-five varieties and selections of soybeans were tested for yield of seed and hay on the Agronomy farm at Morgantown, and eleven varieties and selections were grown on the Lakin Experiment farm in Mason County.

The varieties giving good yields of hay as well as seed at Morgantown were Haberlandt, Peking Selection I-21-7, Peking, Wilson, and Hamilton.

Certain facts which may serve as a guide in the choice of varieties are enumerated, and seven of the more important varieties are briefly described.

Data are presented showing the relative yield of certain varieties when grown in cultivated vs. solid drill plats at the Lakin farm.

At Lakin Haberlandt, Hamilton, Sherwood, Virginia, and Peking I-21-7 gave the best yields of both hay and seed.

Bulletin 244 November, 1931

JAN 9 1932

Report of the West Virginia Agricultural Experiment Station for the Biennium Ending June 30, 1930

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

An adequate livestock program must be built on a foundation of research

Report of the West Virginia Agricultural Experiment Station for the Period from July 1, 1928, to June 30, 1930

by F. D. FROMME

DIRECTOR'S STATEMENT

PREVIOUS REPORTS

THIS ISSUE resumes the series of reports of the West Virginia Agricultural Experiment Station which was discontinued in 1916. The work of the Experiment Station from its establishment in 1888 to 1916 is recorded in a continuous series of annual and biennial reports. The series was interrupted in 1916 because of activities associated with the war emergency and until now it had not been resumed. Since the present report dates from July 1, 1928, the lapse in the series is the period from July 1, 1916, to June 30, 1928, a period of twelve years.

The first report, issued in 1889 by John A. Myers, covered the work of the first year, ending June 30, 1888. This was followed by a series of annual reports, fifteen in all, to and including the year 1902. The first eleven reports by Director Myers cover the period from 1888 to 1898, and the last four by James H. Stewart cover the fiscal years 1899 to 1902.

A series of eight biennial reports succeeds the annual reports and covers the period from 1901 to 1916, inclusive. As will be noted, the first biennial report, that for 1901 and 1902, overlaps the period of the annual reports. It is essentially a statement of work and expenditures of State funds for the control of San Jose scale and other injurious insects and plant diseases. The next four reports, 1903-1904, 1905-1906, 1907-1908, and 1909-1910 were similar in character. The biennial reports for 1911-1912, 1913-1914, and 1915-1916 deal with the general work of the Experiment Station and also include reports of resident instruction and extension work. The first five reports of this series were prepared by James H. Stewart, the next two by E. Dwight Sanderson, and the last by John Lee Coulter.

Although the publication of separate reports was discontinued in 1917, the biennial reports of the West Virginia State Board of Control provide a continuous record of the business affairs of the Experiment Station and also contain brief statements of progress in research. These reports cover the period from October 1, 1908, to date and include reports of the directors of the Experiment Station together with similar reports of other State institutions. The reports which deal with the periods covered, together with the names of the directors, are included in the following citations:

Biennial Report, West Virginia State Board of Control, v. I., p. 253-260, Oct. 1, 1908-Sept. 30, 1910, James H. Stewart; v. II:2, p. 63-76, Oct. 1, 1910-Sept. 30, 1912; v. III:2, p. 565-597, Oct. 1, 1912-June 30, 1914, E. Dwight Sanderson; v. IV:2, p. 521-564, July 1, 1914-June 30, 1916; v. V:2, p. 453-469, July 1, 1916-June 30, 1918; v. VI:2, p. 501-524, July 1, 1918-June 30, 1920, John L. Coulter; v. VII:2, p. 467-502, July 1, 1920-June 30, 1922; v. VIII:2, p. 440-474, July 1, 1922-June 30, 1924; v. IX:2, p. 109-131, July 1, 1924-June 30, 1927, Henry G. Knight; v. X:2, p. 71-94, July 1, 1927-June 30, 1930, F. D. Fromme.

The new series of reports as planned with this first issue will deal primarily with progress reports of research, and will be published biennially. Changes in personnel, publications, plans of work, and important additions to equipment, buildings, and land will also be included. The reports to the State Board of Control will continue to be more essentially reports of business activities, while the new series of separate reports will deal essentially with progress in research.

CURRENT RESEARCH IN REVIEW

The results of the research work conducted during the biennium are presented as brief summaries which are intended to afford the reader a general picture of the scope and character of the work of the Experiment Station, with much of the detail omitted. The 80 summaries which follow relate the most salient features of as many distinct research studies. The volume of the research program and the great amount of detail that supports the brief statements of conclusions will not be apparent except to the reader who is acquainted with the conduct of research and with the exacting requirements necessary to establish the truth of a conclusion.

The object of research is to learn and record the truth. Although a truth once learned usually may be stated in simple terms, the process by which the truth is established is rarely a simple one. This is especially true of research dealing with animals and plants because of the great variability inherent in living matter and in the conditions which surround it.

It might be assumed, for example, that the truth of the simple statement, "Feed has no appreciable effect on the color of beef", could be established by relatively simple means, even by general observation.

As a matter of fact, however, general observation has led to the belief that color may be affected by feed and that grass-fed beef is likely to be darker in color than grain-fed beef. Because of this belief a degree of prejudice and discrimination against grass-fed beef has existed on certain markets. In order to learn the truth as exactly and fully as possible it was necessary for the department of animal husbandry to make accurate comparisons of the meat of a considerable number of steers. Steers of similar breeding were obtained. They were selected for uniformity, were fed under similar conditions for identical periods, and were killed and dressed alike. Color readings were made on identical cuts with the spectrophotometer, which gives an accurate measure of color, eliminating the errors inherent in the human eye. The readings showed no appreciable difference between the grass and grain-fed beef, and because of the careful regulation of the conditions of the experiment it was possible to state as a fact that feed does not affect color.

Again, the simple statement that Gopher oats is superior to other varieties for West Virginia can be made only after a series of trials in several localities under an average range of seasons. The seed of varieties under comparison must be pure. The seeding must be planned so that inequalities in soil are avoided or minimized. The rate of seeding, condition of maturity at harvest, and moisture content at threshing must be regulated to afford exact comparisons. Yields must be accurately recorded and calculations checked for possible errors.

In order to have a complete report of the research of the Experiment Station it is necessary, therefore, that we read between the lines of the brief summaries something of the details of planning and execution of the experiments, of the knowledge of previous experience on which they are built, of the technical skill, equipment, and facilities employed, and of the requirements of time and place.

Completed researches are published from time to time as bulletins or as technical papers in scientific journals. The number of these publications from the Experiment Station during the biennium has been larger than for any like period in its history. A complete list is shown on pages 48 to 55 of this report.

COOPERATION WITH OTHER RESEARCH AGENCIES

If agricultural production and distribution were a self-sufficient enterprise, limited within the confines of each state, our experiment stations might be institutions serving but their own commonwealths. But farming is a national occupation, and the host of problems facing the producer are of nation-wide significance. The lines of research must reach beyond the boundaries of states, particularly if regional and national problems are to be solved.

Nine projects now mark the cooperative research work between the West Virginia Station and the United States Department of

Agriculture. Of these, three are pursued jointly as regional projects with neighboring stations. In the field of agronomy, joint investigations have been under way both with pasture lands and tobacco crops. The Office of Tobacco Investigations of the U. S. Department of Agriculture cooperates with the department of agronomy at the Lakin Experiment farm in Mason County. On rich bottom lands crosses have been made between Maryland Mammoth, Kelley, and Pepper, all high-yielding strains but susceptible to rootrot, and a standup and non-standup strain of Burley, both of them resistant to rootrot. The progeny is being studied with the aim to isolate a strain which combines the desirable features of both Burley and Maryland Mammoth tobaccoes.

In order to determine the best practice, from the dairymen's viewpoint, in pasture fertilization, extensive pasture studies were begun in the spring of 1930 by the departments of agronomy and dairy husbandry in cooperation with the federal Office of Forage Crops Investigations. At the Reymann Memorial Farms at Wardensville about 50 acres are devoted to this experiment. Different kinds and amounts of fertilizers are applied to pasture plots, which are grazed by a herd of from 40 to 50 Ayrshire cows. A record is kept of the pasture days and of the amount of milk produced from each of the treated plots, and changes in the character of the pasture grasses due to treatment are noted. Outlying trials also are conducted in Monongalia, Preston, and Grant counties. The pasture problem is one of the most important farm problems in West Virginia, where much of the land area is suited to pastures, and where some of the choicest bluegrass pasture land in the country is found.

The effect of breed of sire on the production and quality of lambs has been the subject of a cooperative project between the department of animal husbandry and the federal Bureau of Animal Industry. At Hillsboro, Pocahontas County, rams of the Southdown, Shropshire, Hampshire, and Cheviot breeds were mated to 120 native ewes. The West Virginia Station carried the study up to the marketing stage, when the government undertook a detailed carcass study of the lambs in pursuit of a national project on a study of the factors influencing the quality and palatability of meat. A similar agreement is in force between the federal Bureau and the department of animal husbandry in a project at Lewisburg, Greenbrier County, on fattening 40 two-year-old steers on grass with and without a grain supplement. The facilities of a large research institution such as the U. S. Department of Agriculture in carrying out intensive meat studies thus are made available for the mutual benefit of both State and Nation.

The heart of the eastern apple-producing region of the United States is the scene of a cooperative study between the experiment stations of West Virginia, Virginia, and Pennsylvania and the U. S. Department of Agriculture, concerning the influence of climate, topography, soil, varieties, and cultural practices on the yield of apples. This includes a study of orchard management and of the

place of orchards in the farm organization of the apple section of eastern West Virginia, as well as a study of markets, costs, and methods of marketing apples in that section. Another project pursued in cooperation with the federal Bureau of Agricultural Economics and the Virginia Polytechnic Institute, now come to a close, concerns the systems of livestock farming in West Virginia and southwestern Virginia as observed in the leading livestock producing counties of these two states. A study of the status, trends, place, and outlook of the finewool sheep industry in the northern part of West Virginia is matched by a like study in both Ohio and Pennsylvania. The government cooperates in the matter of providing the world outlook on fine-wool sheep and in interpreting price trends. A three-year study of boys' and girls' club work in the State, concluded during the biennium, has been carried on in cooperation with the Division of Farm Population and Rural Life, U. S. D. A.

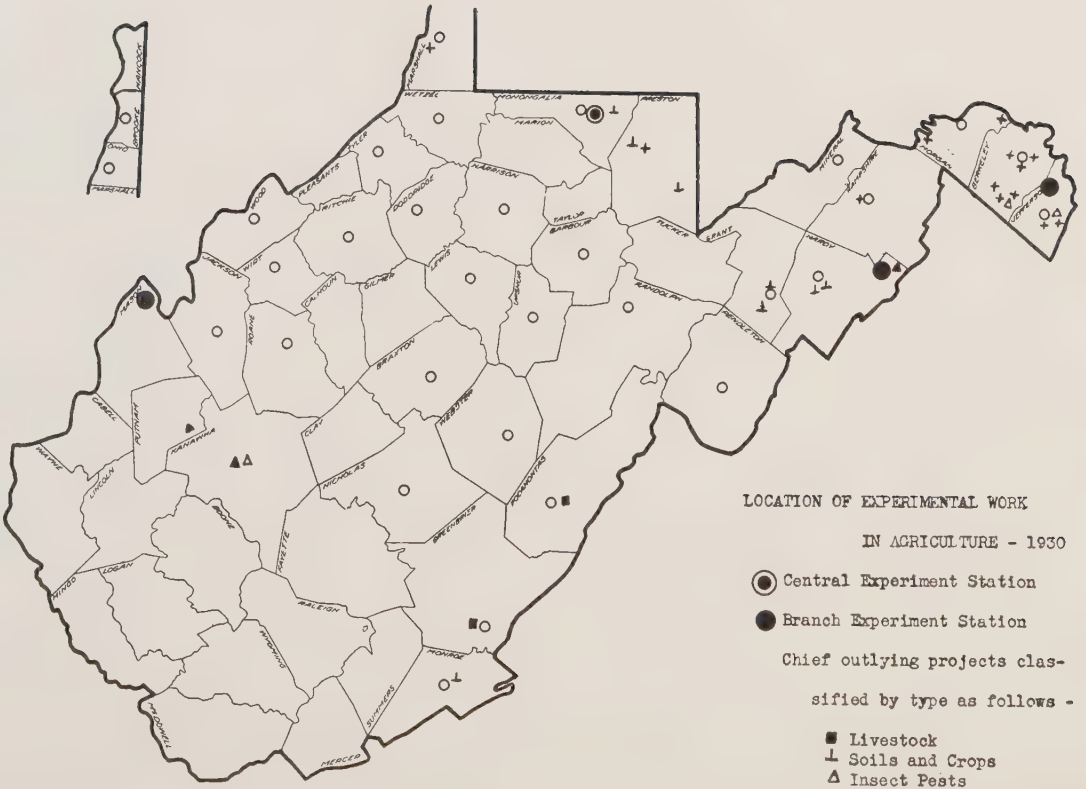
A single project between the department of dairy husbandry and the Bureau of Dairy Industry of the U. S. Department of Agriculture concerns an investigation of the effects of the continued use of proven sires on the milk-producing ability of purebred dairy animals. The project is carried on with the Reymann Memorial Farms herd of Ayrshire cattle at Wardensville and with the Station's Holstein herd at Morgantown.

FIELD DAYS

Of practical value in acquainting large numbers of farmers with the nature and results of experimental work in the several fields of production are the Field Days held annually at Morgantown and at branch stations under the auspices of the Experiment Station. The summer of 1928 witnessed the first one-day field meeting held at Morgantown, with visits to the agronomy, dairy, horticulture, livestock, and poultry farms; explanations of research projects by the heads of the respective departments; and addresses by University and Station officials. The field day has become an annual event with steadily increasing attendance. At the Lakin Experiment farm, field days offering inspections of agronomic and vegetable research work have been held annually since 1927.

NEW LAND AND BUILDINGS

The most important addition to the facilities and equipment of the Experiment Station in recent years was made during the latter part of the biennium through the purchase of an experimental farm in Jefferson County. Although the Station has contributed much in the past to the development of fruit growing in West Virginia through studies conducted at Morgantown, its efforts have been handicapped for lack of opportunity to work under the same conditions of soil and climate as occur in the large commercial orchard sections. The new experimental farm, which lies in the heart of the


LOCATION OF EXPERIMENTAL WORK
IN AGRICULTURE - 1930
Central Experiment Station
Branch Experiment Station
Chief outlying projects classified by type as follows -
Livestock
Soils and Crops
Insect Pests
Plant Diseases
Farm Economics
Fruits and Vegetables

extensive orchard belt of the Eastern Panhandle, supplies this opportunity in very satisfactory measure. Except for a few acres occupied by farm buildings the entire 160 acres are available for experimental work. Plans for the new farm, which becomes one of three branch stations of the Agricultural Experiment Station under the name of University Experiment farm, include an extensive study of root stocks for apples in cooperation with the U. S. Department of Agriculture; also studies of orchard cover crops, orchard fertilization, pruning, orchard management, and disease and insect control. Problems of peach and cherry production will also receive attention. Other studies in contemplation include the production of crops of interest to dairymen and livestock farmers. Studies of the value of deep tillage for field crops and orchards are also planned. The large residence at the farm has been remodeled to provide offices and laboratories for the experimental work, and a stationary spray plant operated by electric motor has been installed for studies of the hydrant system of orchard spraying.

New buildings erected on the farms of the Experiment Station during the biennium include a greenhouse on the University campus at Morgantown for the use of the departments of agronomy and plant pathology; a modern hospital barn on the Dairy farm for housing stock employed in a study of infectious abortion; a sheep barn, an experimental shed for the study of parasitic diseases of sheep and calves, and a quarantine shed for sick animals on the Livestock farm; two metal brooder houses on the Poultry farm; and on the Lakin Experiment farm two hot-water heated hotbeds, with capacity for 30,000 plants, used for the forcing of tomatoes, egg plants, and peppers in variety tests.

RESEARCH AN INVESTMENT, NOT AN EXPENDITURE

The Agricultural Experiment Station is a State institution supported in part from State funds, in part from Federal funds, and in part from the sale of produce. Its business is to conduct research directed toward the improvement of agriculture, not only in the production of crops and livestock but also in their utilization and disposal. The problems of marketing have received especial attention in recent years and demand still larger services in the future. The problems of the farm home and those pertaining to rural community life likewise fall within the scope of the Station and deserve more attention than present limited facilities can provide.

Although directed especially to the problems of agriculture, the benefits of agricultural research are shared in large measure by the entire population.

Improvements in methods of production have reduced costs to the consumer of farm products; they have increased the labor output of the individual, thus releasing surplus man power to industry; and they have insured adequate supplies of wholesome food and raw

materials to the State and Nation as an essential guarantee of prosperous growth and a major bulwark of defense.

Improvements in processing, transportation, and storage have reduced the wastes of perishable products and insured ample supplies in seasons and years of inadequate yield. Famine as a factor in human welfare has been eliminated by those nations which support an adequate agricultural program.

Improvements in marketing, especially those resulting through the cooperation of producers, have reduced the costs of distribution and have insured more uniform supplies of graded, quality produce to the consumer.

The public is served again through the knowledge of food values and balance in diets, the greater part of which has been contributed by agricultural experiment stations. Studies of the role of the vitamins in nutrition have revolutionized the food habits of the nation.

The use of public funds for the continued and increased support of research in agriculture is clearly in the public interest.

REPORTS OF RESEARCH

The reports which follow concern the status of research work in the Experiment Station for the biennium 1928-30.

AGRICULTURAL CHEMISTRY

Composition of Skeletons

In view of the large amount of work being done on mineral deposition in the skeletons of animals and because of the wide diversity of methods used by various investigators in securing and applying data on skeletal composition, it seemed worth while to make a detailed study of the various parts ordinarily used in such work. The results of this investigation will materially assist in determining what bones, if any, are most representative of the skeleton and which are first to show mineral deficiency.

A study was begun by R. B. Dustman and C. E. Weakley, Jr., in 1929, representing the outgrowth of various bone analyses requested by the departments of animal husbandry and dairy husbandry. To date the moisture and ether extractable material on several hundred individual hog bones has been determined. The results secured with these determinations show that when the different bones are compared with one another they fall into a definite sequence in which they are paired. Further work on the ash, calcium, and phosphorus content of these bones is going forward. In addition to the hog bones, samples of rat bones have been taken and are being held for similar analysis.

Miscellaneous Chemical Investigations

Miscellaneous chemical investigations by R. B. Dustman and L. P. Hansen include one on the effect of various gases of ultra-violet light on colored and uncolored fruit. This phase has been extended into a separate investigation of pigmentation and ripening phenomena.

In a study begun in 1927, broomsedge (A. VIRGINICUS) and poverty grass (D. SPICATA) were analyzed at regular intervals of growth. The early growth of both grasses was found characterized by a high protein and low fiber content when compared to the later growth stages. Best utilization of the pasturage afforded by them involves reasonably early, close, and continuous grazing before the mid-summer decline in nutritive value takes place. By frequent cutting it has been found possible to maintain a relatively high protein and low fiber content throughout most of the summer months. Analysis of orchard grass (D. GLOMERATA) showed a very high protein content in early May and a higher protein content when grown in shaded areas than when grown in the open.

Other investigations include color reactions of certain aldehydes, ketones, quinones, and oximes with compounds containing active methylene groups; a quantitative study of certain sources of error involved in the Munsen-Walker method; condensation of naphthalene and chloracetyl chloride; and a study of methods for the determination of pectins.

The work of the department also includes analyses of grains, grasses, silage, feedstuffs, spray materials, fruit buds, blood, bones, etc. for the several departments of the Experiment Station.

ANIMAL HUSBANDRY

Feed has no Appreciable Effect on Color of Beef

The studies of J. H. Longwell on the color of beef contradict a popular belief that the meat of grass-fed cattle is darker than that of grain-fed cattle. Spectrophotometric color determinations have been made on samples of beef from about 100 experimental cattle. These cattle received various feeds such as pasture alone, pasture and grain, and pasture alone followed by grain and hay. There was no evidence that grass-finished beef is different in color from grain-fed beef showing the same degree of finish.

High-Grade Calves Better Than Low-Grades for Beef Production

In a two-year test conducted by E. A. Livesay, high-grade Hereford calves proved to be more valuable for beef production than low-grade calves. The cost of gains was about equal for the two grades, but when marketed as two-year-old steers it was found that the low-grade calves had proved to be worth only three-fifths as much as the high-grade calves at the start of the test. This work emphasizes the value of the use of purebred bulls and that low-grade calves should

be marketed as veals and not developed into two or three-year-old steers. Complete details of this work are published in Bulletin 225.

Representative carcass produced from good-to-choice lot of calves on the right and from common lot of calves on the left. Note the fuller and smoother appearance of round, loin, rib, and chuck of the carcass on the right

Advantages of Grain Supplements for Grass-fed Steers

A supplement of corn and cottonseed meal fed to good and medium three-year-old steers on pasture increased the summer gains 37 percent as an average of 3 years' experiments conducted by C. V. Wilson and E. A. Livesay in cooperation with the Bureau of Animal Industry, U. S. D. A. The feeding of grain increased the selling price of both grades of steers more than 10 percent, the medium grade having a slight advantage. Medium steers fed grain made a margin of $6.07 per 100 pounds as compared to $5.62 for the corresponding lot of good grade. Medium and good steers on grass alone made a margin of $4.85 and $4.38 per 100 pounds, respectively.

The gains and finish of three-year-old steers on good pasture can be increased sufficiently by the feeding of a grain supplement to more than offset the additional expense under conditions comparable to those existing at the time the experiments were conducted.

Tests under way with two-year-old steers indicate that satisfactory gains, finish, and yield of meat may be secured by the feeding of a grain supplement on grass. Two-year-old cattle on grass alone do not make satisfactory beef.

Good West Virginia Calves Make Choice Baby-Beef

West Virginia-bred calves fed and marketed as baby beeves gave an average value of $54.64 at the time they were placed on feed in a series of tests by E. A. Livesay extending over a period of six years (1924-1930). Spring calves were bought during the late fall and started on feed each year during the first half of December. These calves were fed a period of about 200 days and sold on the Pittsburgh market. They were considered choice baby beeves weighing an average of slightly more than 900 pounds. These calves were fattened on a ration of corn, oats, linseed meal, cottonseed meal, corn silage, and mixed hay. The average return per calf for the six-year period (counting cost of all feeds fed) was $54.64. This was considered a very good price for calves during the period of the tests. It is not recommended that farmers in general try to market their calves through the baby-beef route. However, there are some farmers producing their own calves who could follow such a system for a period of years with the assurance that the calves will give a fair return.

Alfalfa and Rape Excellent Forage Crops for Hogs

In feeding trials conducted by J. H. Longwell which have included a number of forage crops, alfalfa and rape have consistently given good results. Among the perennials alfalfa has no equal. It furnishes pasture from early spring until fall and is quite palatable. Pigs eating it developed into thrifty, strong-boned individuals.

Rape has also proved highly satisfactory. If seeded by the middle of April it is ready for pasture by June 15. Pigs on rape pasture

were thrifty, grew rapidly, and made economical gains. The Dwarf Essex variety was used in all trials.

Buckwheat Middlings a Good Protein Supplement for Pigs

Buckwheat middlings, when used to supply a part of the protein in rations for pigs, has proved equal to or slightly better than linseed oilmeal and cottonseed oilmeal. Protein supplemental mixtures consisting of 2 parts tankage, 1 part linseed oilmeal, and 1 part alfalfa meal; the same proportions of tankage, cottonseed oilmeal, and alfalfa meal; and tankage, buckwheat middlings, and alfalfa meal, have all given excellent results when fed as supplements to corn. Other mixtures, the same as the above except that tankage was replaced with fishmeal, gave equally good results. But those mixtures containing buckwheat middlings resulted in more rapid gains and required less feed to produce gains.

These trials have been conducted by J. H. Longwell with pigs from weaning time until the pigs were marketed, weighing 200 to 250 pounds.

Vitamins in Oats

Previous work at this Station indicated the presence of sufficient vitamins A and D in oats to correct the deficiency of white corn with respect to these two vitamins.

Pig showing typical posterior paralysis developed on basal ration deficient in vitamins A and D

Four lots of five pigs each were used in a new series of tests by J. H. Longwell. The pigs in all lots were similar as to breeding, age, size, and sex. Lot 1, the check lot, received a ration in which adequate amounts of vitamins A and D were provided by using yellow corn and alfalfa meal; Lot 2 was deficient in vitamins A and D, containing white corn, buckwheat middlings, and tankage; Lots 3 and 4 received the white corn ration with oats added. Lot 3 was con-

fined to the barn; Lot 4 was allowed to run in an outside pen where they were exposed to sunlight.

All the pigs in Lot 1 grew normally to weights of approximately 225 pounds, none of them showing any symptoms of vitamin deficiency.

The pigs in Lots 2, 3, and 4 grew normally for about 150 days. At this time some of the pigs began to show symptoms of vitamin A and D deficiencies. The seriousness of the symptoms gradually increased and finally included all the pigs in these three lots. Neither oats nor sunlight appeared to correct the deficiencies of the ration used.

Each pig was slaughtered when it reached a weight of about 225 pounds, or when it became unable to stand. Several bones were removed from each pig and subjected to a number of chemical determinations. There appeared to be no difference in the chemical composition of the bones of pigs from different lots. The deficiency of the white corn ration was apparently vitamin A and not D, and this deficiency was not corrected by adding oats.

Breed of Sire as a Factor in Lamb Production

Rams of the Southdown, Shropshire, Hampshire, and Cheviot breeds have been compared for the production of market lambs when used on native West Virginia ewes of grade Hampshire type in an experiment of four years' duration that has just been concluded. The work is cooperative with the Bureau of Animal Industry, U. S. D. A., with C. V. Wilson and E. A. Livesay actively engaged for the Experiment Station. Single lambs sired by Southdown, Shropshire, and Cheviot rams had an approximately equal birth weight of 9½ pounds, while lambs sired by Hampshire rams were approximately three-fourths of a pound heavier, averaging 10¼ pounds. Single lambs sired by each of the breeds were approximately 2 pounds heavier at birth than twin lambs by the same sire.

At 145 days old, single lambs by Shropshire and Hampshire rams were equal in weight and from 4 to 5 pounds heavier than lambs by Southdown and Cheviot rams that were likewise approximately equal in weight.

Single lambs by any of the sires used weighed on the average from 75 to 80 pounds at a mean age of 145 days.

In general, the results obtained to date from this experiment indicate no marked superiority of any one of the four breeds of rams over the other three for the production of market lambs. There is evidence that each breed has certain superior characteristics and would likely give a desired result when used for a definite purpose, such as to increase size, secure compactness, or change fleece characteristics of ewe lambs kept for breeding purposes. The type of ewe to which the ram is to be bred should influence the breed of ram chosen.

Based on the general results secured the use of any of the four breeds may be recommended.

Continued Use of Proven Sires

The long-time breeding experiment to determine the results of the continued use of proven sires on the Ayrshire herd at the Reymann Memorial Experimental farms is in progress by H. O. Henderson, R. A. Ackerman, and L. F. Sutton in cooperation with the Bureau of Dairy Industry, U. S. D. A. This herd consists of about 120 females. Only proven sires are used. The cows in the foundation herd were mated to Hilltop Major Douglas; his daughters were mated to Penshurst Schoolmaster and to Leto; and their daughters are being mated to Yellow Kate's Exchange of Penshurst, Willowmoor Peter Pan 93rd, and Penshurst Sir Robert. There are now several animals in the herd with four generations of proven sires in their pedigree. The heifers are all tested for Roll of Honor during their first lactation and the entire herd is in the Herd Test. Conditions as to feeding and management are kept as uniform as possible.

Linebreeding vs. Outcrossing

A study of line-breeding vs. outcrossing was begun with the Holstein herd eight years ago and is being conducted under the direction of H. O. Henderson and K. S. Morrow. The study has been changed in scope so that it is now a study of the effect of proven dairy sires. Not all of the sires used in the past have been proven.

The foundation sire was Meadowholm Ona Pontiac Hartog. Fourteen daughter-dam comparisons on mature-equivalent basis are available for this sire. The daughters produced an average of 15,029 pounds of milk and 524.6 pounds of butterfat while their dams averaged 15,783 pounds of milk and 525.2 pounds of butterfat. This would indicate that the sire just about maintained the production of the herd on the same level.

The second sire was Sir Colantha Ormsby Hero. He was used on the daughter of the proven bull. The average of his first six freshening daughters was 14,641 pounds of milk and 514.2 pounds of butterfat, while their dams produced 16,692 pounds of milk and 563.0 pounds of butterfat. He decreased the production by 2,051 pounds of milk and 49 pounds of butterfat.

The third sire used was Varsity Piebe La Vertex. There are now 16 of his daughters in the herd but they have not come in milk in sufficient numbers to indicate his effect upon the herd.

Effect of Low Calcium and Low Phosphorus Rations on Growing Dairy Heifers

A continuation of the study of the effects of low-calcium and low-phosphorus rations upon the growth of dairy heifers is being conducted by H. O. Henderson and K. S. Morrow of the department of dairy husbandry in cooperation with R. B. Dustman and C. E. Weakley, Jr., of the department of agricultural chemistry. A previous study carried heifers fed rations low in calcium, or low in phosphorus,

or low in both calcium and phosphorus, until they had reached the age of two years without being bred. The present study will continue heifers on similar rations during the period of gestation and lactation.

This study is now in its second year of investigation with eleven animals receiving the various experimental rations. One group is fed a normal ration; one a ration low in calcium; one a ration low in phosphorus; and another a ration low in both calcium and phosphorus. Weekly weights and measurements are made, and the blood

"E 28" was fed a low-calcium-low-phosphorus ration

is analyzed monthly. At present all of the heifers appear in a fairly thrifty condition and no consistent difference can be noted due to the experimental rations. Depraved appetites as evidenced by chewing of the mangers is apparent with the older animals receiving the mineral-deficient rations. The effect of the low phosphorus rations on the inorganic phosphorus content of the blood is very evident, but the analyses of the blood calcium fail to show any definite correlation between that factor and the calcium contained in the food.

In the department of agricultural chemistry calcium and phosphorus determinations have been made on the blood from eleven heifers. It has been found possible to vary the inorganic phosphorus content of the blood by feeding rations high or low in phosphorus. The results with calcium are still uncertain. Large fluctuation in the inorganic phosphorus content of blood has been found from day to day. Phosphorus content is shown to decrease with age. There are some indications that daily withdrawal of blood from these animals may affect the calcium content, and that samples taken with disturbance to the animal, as from a nervous animal, likewise affect the calcium content. The daily fluctuations in calcium were found less pronounced than for phosphorus content.

Control of Infectious Abortion in Cows by Herd Management and Testing

A study of the control of infectious abortion (Brucella abortus infection) by herd management and testing has been inaugurated by J. H. Rietz, K. S. Morrow, and H. O. Henderson. Ten days previous to the time due to calve all animals in the dairy herd which react to the agglutination test are isolated in the hospital barn. They are retained in the barn until all uterine discharges cease. Monthly blood tests are made of the entire herd.

The study of abortion control by management and testing must necessarily be carried on over several years. With the present facilities of isolation it is hoped that valuable information will be accumulated in the University herd which may be applicable to farm conditions so that a definite program for the complete elimination of this disease may be offered to dairy farmers having infected herds.

Water Consumption of Dairy Animals

A study of the water consumption of dairy animals is being made by K. S. Morrow and R. A. Ackerman. Great variation has been found in the amount of water consumed by individual animals kept under the same conditions and fed the same rations. Some yearling heifers will consume as little as 25 pounds of water per day while others will consume 75 pounds under identical conditions.

The character of the ration is evidently a factor affecting water consumption. Two cows in milk, when receiving mangels in their ration, averaged, during 28 days, 40.39 pounds and 73.49 pounds of water daily. The following four weeks, when corn silage was fed in place of the mangels, the daily amount of water consumed was 75.08 pounds and 101.0 pounds respectively. No detrimental results have been noted in the health and growth of calves which are given water while being fed milk. Such a study has been continued until the heifers are 6 months of age.

Growth Study of Ayrshire Cattle

A study of the growth of Ayrshire cattle has been undertaken at the Reymann Memorial farms under the supervision of R. A. Ackerman and H. O. Henderson. During the first week of each month all animals in the herd are weighed and measured as to height of withers and depth of heart girth. Data are kept on both males and females. No attempt has been made to analyze these data.

Cost of Raising Dairy Heifers

A record of the amount of feed required to feed dairy heifers from birth until maturity has been kept at the dairy farm at Morgantown and in the Ayrshire herd at the Reymann Memorial farms at Wardensville. Data on about 50 individuals have been collected.

Along with the feed consumed, a record is kept of the growth of the heifers. They are weighed and their height at withers is determined every month. (No attempt has been made to assemble this material as it was thought advisable to get as many data as possible before appraising it.)

Varieties of Pasture for Milk Production

A study to determine the relative merits of different varieties of pastures for milk production and to establish a rotation of pasture which could be recommended to West Virginia dairymen has been inaugurated by H. O. Henderson, R. J. Garber, and R. A. Ackerman. At Wardensville a series of eight plots has been laid out, two of which have been seeded to bluegrass and white clover; two to oats, Canada field peas, sweet clover, and Sudan grass; two to oats and sweet clover; and two to Sudan grass. During the past year, the driest season on record, all of the pastures were practically worthless by July 15th. The sweet-clover pastures were found to withstand the drought better than did the bluegrass-white clover mixture, while the Sudan grass failed to make much growth because of the drought. The sweet clover furnished more pasture, remained green, and was pastured eleven days after the bluegrass—white clover pasture had "burned up".

Sweet-clover pasture was not eaten well for the first two or three days, but beginning about the fourth day the cows ate it much better, and after a week or two they seemed to relish it. It had a good laxative effect on the animals, and no ill effects were noted.

Roots as a Feed for Dairy Cows

Of especial interest to those who keep a small number of cows and find it unprofitable to have a silo, but who still wish to supply some succulent feed for the winter season, is the investigation conducted by K. S. Morrow and H. O. Henderson on the comparison of mangels and corn silage. Mangels have yielded on the average from 25 to 30 tons per acre on the Station farm at Morgantown on land that will yield from 10 to 12 tons of corn silage. During some seasons, certain varieties have yielded as high as 40 to 50 tons per acre.

Analyses have shown that corn silage contains about 2½ times as much dry matter as does an equal amount of mangels. Three trials have been conducted in which one group of dairy cows were fed corn silage with hay and grain, and another group were fed mangels with hay and grain, both groups being fed the same amount of dry matter. The rations were alternated by the reversal method, so that each group received the silage ration for a period of four weeks, and the ration containing mangels for a similar period. Under this procedure there was no appreciable difference in the amount of butterfat produced by cows when fed the two kinds of feeds. There did seem, however, to be a slight difference in milk production in favor

of the group receiving the mangels. This was probably due to the extra amount of water obtained from the mangels. The water consumption of the animals was measured by means of water meters attached to the individual drinking cups. Less water was consumed when the cows were receiving the ration containing mangels, but more data must be taken before drawing definite conclusions as to the effect of the water in the food upon milk and butterfat production. The data at hand, however, would indicate that mangels may be substituted for corn silage when fed on the equal dry-matter basis.

Soybean vs. Alfalfa Hay for Milk Production

A continuation of the study of soybean hay and alfalfa hay for milk production has been carried on by H. O. Henderson. The results of the first two feeding trials were slightly in favor of the soybean hay and were reported in Bulletin 181 of this Station. Two more trials have been run under the same plan by using the reversal feeding method, in which one group of cows were fed alfalfa hay and a grain ration for one period and then changed to soybean hay, while the other group were first fed soybean hay and later changed to alfalfa hay.

The results of these two trials were slightly in favor of the alfalfa hay. The alfalfa hay was home-grown and of a higher quality than that used in the previous trials, while the soybean hay was allowed to become rather coarse before harvesting. The cows refused 23 percent of the soybean hay by weight during the first of these trials and 10 percent during the second of these trials, while they refused only 3 percent of the alfalfa hay during the first and none during the second of these trials. This refuse consisted of the coarse stems.

During the first of these trials, the ten cows when fed alfalfa hay produced a total of 16.0 pounds of milk and 2.22 pounds of butterfat more than they did when they were fed soybean hay over a period of 21 days, while in the second trial the ten cows fed alfalfa hay produced 167.2 pounds of milk and 3.27 pounds of butterfat more than when fed soybean hay. The cows in both instances maintained their weight just as well on the one ration as on the other.

When all four trials are taken into consideration, it is found that there is less than 0.2 pounds of butterfat difference in the total amount of butterfat produced by the 40 cows when fed the different kinds of hay, over a period of 21 days. In conclusion it can be said that if the soybean hay is cut before it becomes coarse, it should equal alfalfa hay for the production of milk and butterfat.

Microflora of Raw and Pasteurized Grade-A Milk

A study of the microflora of high-grade milk before and after pasteurization has been made by L. M. Thurston and H. C. Olson.

Efficiency of pasteurization was determined for 103 samples of milk and was found to increase as the bacteria count of the raw

milk increased. Thus efficiency of pasteurization is lower for Grade-A milk than for milk of higher bacteria content. This is explained on the basis that a fairly constant number of resistant organisms exist in milk of any grade, making the proportion surviving in milk of low initial count high as compared to milk of higher initial count. It was also found that the efficiency of pasteurization was more variable for milk of low initial counts than for those of higher counts.

The proportion of types of bacteria in the milk before and after pasteurization differs. There was a decided increase in proportion of acid-forming bacteria in the pasteurized milk over those present in the raw. These organisms were predominantly of the bacillus form. The proportion of acid-coagulating bacteria decreased because of pasteurization. In seeking the explanation it was found that the organisms producing acid-coagulation were mostly Streptococci, which were destroyed more efficiently by pasteurization than the Bacilli, which were mostly acid formers. The proportion of inert bacteria increased on pasteurization, as did the peptonizing organisms, but the alkali formers decreased.

Attempts to determine whether the apparent increase in numbers of bacteria in pasteurized milk was due to breaking of clumps failed because the milk used contained so few bacteria that microscopic counts proved impossible.

In tests of keeping quality of raw and pasteurized Grade-A milk the pasteurized milk was found to keep considerably longer than the corresponding raw milk in each of a number of trials. Coagulation of the raw milk in these trials was due to the acid which developed, but evidence indicated that coagulation of the pasteurized milk was due to a rennin-like enzyme secreted by the bacteria.

Flavor in Dairy Products

A study to determine the constituents of milk that contribute to the flavor of dairy products has been inaugurated by L. M. Thurston. A series of trials has been carried out comparing the flavors of normal whole milk with those of standardized buttermilk obtained from the same batch of milk and with standardized skimmilk from the same original source. Standardization consisted in bringing the content of the buttermilk and skimmilk to that of normal milk. The skimmilk was standardized by adding cream containing fat which was washed 10 to 15 times by dilution and reseparation and which should contain a minimum of fat-globule films. The buttermilk already rich in fat-globule films was standardized by the addition of unwashed cream. There was a perceptible graduation in rich flavor for each of the three samples in every case, in the order of standardized skimmilk, normal whole milk, and standardized buttermilk. This is in confirmation of the theory that fat-globule films do give milk some of its rich flavor.

Causes for Poor Quality Cream Shipped in less than Carlots

A study of the causes for poor quality cream shipped in less than carload lots has been started by L. M. Thurston, H. O. Henderson, and R. A. Ackerman. An especially good opportunity for this study is provided with the cream obtained from the herd at the Reymann Memorial Experimental farm which is shipped to Washington, D. C., daily. Observation is made at Wardensville as to the temperature, bacteria count, flavor, etc., and the same is obtained upon arrival of the cream at Washington about 15 hours later. Cream is shipped in different types of cans and under various conditions. The results of such a study should be of interest to the many cream shippers in West Virginia.

Manufacture of Sweet-Curd, Rennet-Coagulated Cottage Cheese

A study of the manufacture of sweet-curd, rennet-coagulated cottage cheese conducted by L. M. Thurston is yielding some very interesting results.

It was found that the acidity of the whey at the time of cutting the curd is the most important single factor concerned in the manufacturing process. Regardless of variations in other factors, a whey-acidity of 0.35 percent or more was found necessary in order to produce curd with a desirable body. When the acidity was lower a rubbery curd always developed. Acidities as high as 0.68 percent were developed, this being the upper limit for this type of cheese, as acid coagulation results independently of the action of rennin in this range. The average acidity at cutting for these batches which produced desirable curds was 0.48 percent, and the majority range as determined by the mean plus and minus the standard deviation was 0.41 to 0.54 percent.

The use of calcium chloride proved of no value in hastening coagulation by rennin or in firming the curd during "cooking".

Variations in amount of rennet extract from 1.33 to 3.33 cc. per 1000 pounds of skimmilk had no apparent effect on the making process or on the character of the curd produced from skimmilk pasteurized at 185° F. for 20 minutes. As these amounts were sufficient to yield a desirable curd and varied more widely than the likely limits of error in measurement under ordinary conditions, greater amounts were tried.

Knowledge gained in this work concerning factors governing the process made it possible to shorten the making time from 18 to 8 hours and thus to manufacture the curd during the day. The chief factor in speeding up the process was the quicker development of lactic acid.

Gassy curd was often encountered and if not overcome resulted in a curd of unclean flavor. The gas can be removed and its effects reduced to an unappreciable minimum by heating the curd in the whey to 150° or higher. These results were obtained from skimmilk

pasteurized at 185° for 20 minutes. Similar setting and cooking methods proved unsatisfactory when applied to milk pasteurized at 145° for 30 minutes according to common practice. Studies are under way to find the reason for this difference and to develop a satisfactory method for milk pasteurized at lower temperatures, as well as for raw milk.

POULTRY HUSBANDRY

Weight of Eggs Fairly Stable for Each Layer

When Leghorns are maintained under average conditions the decrease in egg production due to increasing age is, in round numbers, 20 percent per year, according to conclusions reached by Horace Atwood and T. B. Clark after five years of research into the factors affecting the weight of hen eggs. Data include 86,000 egg-weight records, 7,800 body-weight records, and the records of mortality from a random sample of 200 single-comb White Leghorn pullets selected in 1925 on the Poultry farm and fed throughout the experiment on a standard laying ration.

The weight of eggs laid by a bird, it was found, is a relatively stable character, persisting from year to year. The heavier birds laid the heavier eggs, but there was no evidence that the birds which became materially heavier with increasing age were either better or poorer layers than their companions which remained lighter. A bird which lays a large number of eggs is as likely to lay large eggs as small ones, and a small pullet is as likely to lay a creditable number of eggs as her larger companion. The younger the pullet when beginning to lay, the better the egg production for the pullet year. This relationship did not hold true during later years. Mortality of the flock was normal. At no time was there an outbreak of an infectious disease. A full account of this project is reported in Bulletin 233.

The Time Factor in Egg Production

It seems probable that the intervals in hours from one egg to another within a cycle are so closely correlated with the process of egg formation that the average length of these intervals may be employed during the first stages of production to indicate the potential fecundity of birds for their entire period of production. In order to shed light on this question eighty pedigreed pullets were selected by T. B. Clark in 1929, to be placed in laying houses when developed. Data re'ating to the following items are being observed: regularity of laying within the cycle, relationship between time of laying and production, relationship between time of laying and length of cycle, inheritance of egg weight, inheritance of length of cycle and time of laying within the cycle, and hatchability as affected by length of cycle.

Egg Incubators Withstand Higher Initial Temperatures

Considerably higher temperatures may be employed with safety at the beginning of the incubating process than have been advised by manufacturers of cabinet-type incubators, according to Horace Atwood. In a study of the proper incubating temperature for the eggs of the domestic fowl in incubators of the cabinet type, begun on the Poultry farm in 1929, six carefully controlled hatches which total 2700 eggs were made in two Petersime incubators during the first year. High initial temperatures have seemed to increase the number of fertile eggs as determined by candling, but so far such temperatures have not increased hatchability. Temperature is relative, not absolute, in relation to humidity and ventilation.

CROPS AND SOILS

Pasture Improvement

Some of West Virginia's bluegrass pastures, particularly those located on soils of limestone origin, rank among the finest known. On the other hand, most of the pastures in the state are located on

Many pastures could be much improved by means of liming and top-dressing with fertilizer

less productive soil and hence are of inferior quality. As the result of a survey made several years ago it was found that on the average approximately 4 acres of pasture were required to support one cow during the grazing season, whereas not more than one-half that amount should be required in a good bluegrass pasture. In view of the extensive area of farm land in West Virginia suitable only for pasture or woodland, the question of pasture improvement is of considerable importance.

In order to study this question an experiment was begun in 1922 by T. E. Odland, C. V. Wilson, H. O. Henderson, and E. P. Dea-

trick in which the effect of certain fertilizer, cultural, and seed treatments were investigated on 44 grazed and ungrazed pasture plats located on each of two farms of the Experiment Station at Morgantown. This investigation has been completed and the results have been published in Experiment Station Bulletin 235. It was found that the use of lime and superphosphate are basic to pasture improvement. On poor, rundown pastures little, if any, benefit may be expected from the use of seed or harrowing unless soil acidity is at least partially corrected by the use of lime, and superphosphate is added to supply a plant-food nutrient deficient in practically all soils of West Virginia.

Date of Soybean Harvest Influences Yields of Wheat and Corn

When soybeans are followed by wheat the results may be unfavorable. Whether the yield of wheat is increased or decreased depends somewhat upon the interval between the soybean harvest and the seeding of wheat. The problem has been studied by D. R. Dodd and R. J. Garber in a series of plats at Morgantown in which soybeans were harvested on three separate dates, August 10, August 30, and September 25. All plats were seeded to wheat on September 28. Good yields were obtained from the plats harvested in August, four and six weeks before seeding, but the reverse was true of the plat harvested in September, three days before seeding. The explanation for the difference was found in analyses of the nitrate content of the soils. Nitrate content is lowest at the time of soybean harvest. It increases rapidly following harvest and within a month the supply is ample for the vigorous growth of wheat. Early harvest of soybeans or the application of some nitrogen fertilizer is, therefore, essential to good yields of wheat as a following crop, since this insures an ample supply of nitrogen in available form for the young wheat plants.

The experience with corn is completely reversed. Late harvest of soybeans is preferred since it provides high nitrate during late spring and summer when the need of the corn crop is greatest.

Rye and Vetch Best as Cover Crops

Rye and vetch have proved more satisfactory as winter cover crops than sweet clover or crimson clover in experiments conducted at Morgantown by R. J. Garber, T. E. Odland, and H. O. Henderson. The clovers have been almost complete failures because of winter killing, while rye and vetch, both alone and in combination, have given excellent winter cover during the nine years of the experiment. The cover crops are grown each year in a rotation of corn and soybeans, being seeded at the last cultivation of corn and following the harvest of soybeans for hay. Appreciable increases in yield of corn as silage have followed the use of the rye and vetch cover crop, but the yields of soybean hay have only been slightly increased. A combination of rye and vetch is preferred to either crop grown separately.

Early Maturing Oats Best for West Virginia

Varieties of oats that mature early yield better under West Virginia conditions than mid-season or late varieties according to tests conducted at Morgantown and Lakin by R. J. Garber, M. M. Hoover, and T. C. McIlvaine. Experimental plantings of a large number of varieties and pure-line selections have been under continuous study since 1921.

Gopher has proved to be one of the high-yielding varieties and is particularly well adapted to West Virginia conditions, as shown also by the results of farmers' trials which have been conducted throughout the State under the supervision of the department of agronomy.

Considerable quantities of Gopher seed are now available through the Crop Improvement Association and indications are that it will soon become the dominant variety in West Virginia. The complete replacement of varieties now in use with high-quality seed of Gopher would, according to estimates based on the experimental trials, increase the production of oats by approximately 2,000,000 bushels a year with no increase in acreage.

Other varieties that have yielded well in the experiments are Iowar and Albion, but Gopher is preferred since it combines earliness, yield, and stiffness of straw.

Wheat Varieties Best Suited to West Virginia

Experimental trials of wheat varieties which have been under way at Morgantown and Lakin for a number of years have been continued during the period of this report. The yields for the entire period have been summarized and compared by M. M. Hoover and R. J. Garber. Eighteen named varieties have been grown at Morgantown for periods varying from two to nine years, and eleven varieties have been grown at Lakin for six years. As would be expected, no single variety can be named as the one best variety for West Virginia but a good choice can be made among three varieties, any one of which can be relied upon to produce better yields than varieties commonly grown in the State. The high yielding varieties are Fulhio, Reliable 80, and Trumbull. Fulhio and Trumbull, both selections of Fultz, are beardless varieties, while Reliable 80, a selection of Gypsy, is bearded. Fulcaster and Ashland have also produced high yields at Morgantown, and Gladden and Mammoth Red have been satisfactory at Lakin. The experiments indicate that the yielding ability of wheat varieties over a period of years is determined very largely by their winter hardiness.

In addition to the trials of named varieties, a number of pure-line selections have been isolated and compared. All but 16 of these selections were discarded in 1929, and the four most promising of these have now been increased for testing in other sections of the State. The latter have produced higher yields than any of the named

varieties and will doubtless be brought into general use within a few years.

Crop Responses to Fertilizers

In 1930 T. C. McIlvaine, W. H. Pierre, R. J. Garber, and K. C. Westover outlined a rather comprehensive project to study the response of different crops to various fertilizers when grown on Wheeling fine sandy loam, an important soil type found along the Ohio river. The crops whose fertilizer responses are being studied are corn, wheat, red clover, soybeans, and potatoes. The relative effect on yield of the three essential plant food nutrients—nitrogen, phosphorus, and potassium—in various amounts and combinations are being determined on more than 300 1/30 acre plats located at the Lakin Experiment farm. A study is also being made of the effect on yield of different methods of placing the fertilizers with reference to the plants: i. e., broadcast, hill, and row applications, alone and in various combinations.

Field experiments such as these are useful in evaluating various fertilizers in terms of increased yields and are also of great importance in that they furnish a basis for more fundamental studies in the greenhouse and laboratory. The goal of this type of soils research is to determine from a laboratory study of soil in a given region just what it needs to grow particular crops. Much information of a fundamental character is still necessary before such a method may be used.

Alfalfa in Relation to Soil Type

A comprehensive study of the growth of alfalfa on the principal soils of West Virginia which has been inaugurated by W. H. Pierre and R. J. Friant during the past year is already yielding results of practical value, although a number of years will necessarily be required to complete a study of this character. Among the points to be determined on the different soil types are the effects of phosphorus and potash fertilization, and the effect of liming to different pH values and percentage base saturation. The effect of mowing and of cultural practices on permanency of stand is also under investigation in several sections of the State.

Early results indicate that the optimum reaction for the growth of alfalfa varies with the soil type, and that good growth of alfalfa may be obtained at pH values considerably below neutrality. All soils but one responded to phosphorus fertilization, the extent of the response varying with the soil type. In the mowing tests the stand was reduced where more than three crops were removed in a single season, the alfalfa being replaced by grass and weeds.

Cowpeas Tolerant to Soil Acidity

Soil acidity studies conducted at the Lakin Experiment farm by T. C. McIlvaine and W. H. Pierre show cowpeas to be much more tolerant of soil acidity, as determined by pH values, than soybeans. The plants were grown in the open in bins 3 feet square, in which the

soils were adjusted by means of lime and sulphuric acid to a range of pH values from 4.01 to 8.13. As will be noted in the accompanying table, cowpeas grew almost as well in the most acid soil, pH 4.01, as in the less acid soils, while the yield of soybeans was greatly reduced at pH 4.04.

TABLE 2.—*Yield of Soybeans and Cowpeas on Soil Brought to Different Degrees of Reaction by the Use of H_2SO_4 and Lime*

Series	pH value of soil	Yield of soybeans (Dry wgt. in grams)	Series	pH value of soil	Yield of cowpeas (Dry wgt. in grams)
A	4.04	183	A	4.01	1138
B	4.42	1350	B	4.40	1277
C	4.73	1517	C	4.64	1338
D	5.49	1523	D	5.49	1164
E	5.79	1441	E	6.00	1159
G	7.22	1679	G	7.17	1195
H	7.76	1889	H	7.74	1292
I	8.12	1586	I	8.13	1105

Hay Tests of Forage Plants, Alone and in Mixtures

In August, 1921, a series of 96 1/40-acre plats was established on the Agronomy farm for the purpose of determining the yields of air-dry hay of several legumes and grasses, both when grown alone and in mixtures. The experiments included varietal and pure culture tests as well as combinations of different hay crops.

In the alfalfa varietal tests Grimm, Canadian variegated, and native common varieties from Kansas, Nebraska, Utah, and other Northwest states were found superior to those from any other section of the United States or foreign countries. Seeds were obtained through the courtesy of the federal Office of Forage Crops Investigations. In a similar study of red clover, it was found that native-grown red clover is superior to seed from foreign countries, particularly from countries with a mild climate like Italy and southern Europe. The Tennessee strain, bred for resistance to Anthracnose, is well adapted to West Virginia conditions and shows no evidence of disease.

Among the pure cultures alfalfa, tall oat grass, and timothy each produced an average yield for the five years in excess of two tons per acre. Italian and perennial rye grasses, meadow fescue, and brome grass did not prove very satisfactory in this experiment.

Among the meadow mixtures, those containing tall oat grass gave the highest yields. Timothy and alfalfa also proved very satisfactory components in increasing the yields in the several mixtures in which they occurred.

Systems of Farming

A large part of the Lakin Experiment farm is located on what is known as Wheeling fine sandy loam, a type of soil that is being used to grow many kinds of field and truck crops in the Ohio river valley section. For this reason a project was outlined five years ago

by T. C. McIlvaine and R. J. Garber to study and compare in field plats different cropping systems with and without the use of lime but with all crops receiving the same amount and kind of fertilizer. There are 270 1/30 acre plats used in this investigation and practically all the important field crops are included in the study.

The use of lime has produced increased yields of all crops except potatoes. In general the higher yields have been obtained from the crop rotations in the "livestock system" of farming, where roughages are fed or used for bedding and the manure is returned to the soil, as compared with the "grain system" of farming, where the grains and first cutting of hay are removed and the crop residues and aftermath on the meadows are returned to the soil. Cowpea stubble turned under has resulted in somewhat greater yields in the following crop of wheat than soybean stubble. The two-year rotations have shown a tendency to produce somewhat lower yields than the three- and four-year rotations.

A Promising Soybean Selection

A selection of the Peking variety of soybeans isolated from the parent variety by R. J. Garber and M. M. Hoover has proved one of the most promising of the soybean varieties and selections tested at Morgantown and Lakin. Especially desirable characteristics of the new selection are the fineness of the stems and the fact that the leaves do not drop as early as in other varieties, thus insuring better quality of hay. Haberlandt, Wilson, and Manchu produced the highest yields of seed, while the Peking selection, Wilson, and Haberlandt led in yield of hay.

A comparison of the yield of seed of three varieties of soybeans when grown in cultivated rows and in solid drill rows showed no significant differences.

Studies relating to field technic have been published as professional papers.

Sweet Clover Breeding Studies

Strains of sweet clover especially adapted to West Virginia and of improved quality as forage and hay are being sought by R. J. Garber, M. M. Hoover, and R. B. Dustman in a recently established project. A large number of new strains have been produced by inbreeding and it is hoped that the desired types may be found among these or other strains produced in similar manner. Under natural conditions sweet clover is normally cross-pollinated and the plants, although varying in some degree, are all much of the same general type. Extreme variations occur, however, when self-pollination is practiced. The strains which have been produced by this method show a wide range of habit of growth, disease resistance, and tolerance to soil conditions. After they have become fixed through selfing for several generations they will be tested for tolerance to acid

soil conditions and for cumarin content, and if possible, strains with low cumarin content that will grow on relatively acid soils will be isolated and propagated for use on the farms of the State.

Controlling Oat Smut by Breeding

One of the diseases which annually cause considerable damage to oats grown in West Virginia is smut. Several years ago an investigation was undertaken by R. J. Garber and N. J. Giddings which had for its object the production of a high-yielding strain of oats resistant to smut. Black Mesdag, a variety known to be resistant to both covered and loose smut, but of little value in other respects, was crossed with Gopher, one of the highest-yielding varieties of oats grown in this section but moderately susceptible to smut. The descendants of this cross are now in the seventh generation. It has been shown that resistance to smut is just as definitely inherited as is color of seed or any other character. Two technical papers giving the results of this work have been published.

A few white-seeded descendants resembling somewhat the Gopher parent but resistant to smut are being increased to determine their relative yielding ability. It is hoped to obtain a variety of oats just as desirable as Gopher and in addition possessing resistance to the disease.

Smut Resistance in Corn

An especially interesting phase of the corn investigations conducted by R. J. Garber and M. M. Hoover has been a study of the susceptibility of inbred strains of corn to the smut disease. A total of 175 selfed strains were compared for smut resistance in 1929 and 120 strains were compared in 1930. Each of the strains has been fixed in its characters through several years of self-pollination, and a remarkable range of susceptibility is exhibited within the series. Some are extremely susceptible, others highly resistant, and others range between these extremes. The strains are not only strikingly different in susceptibility for the plant as a whole but they differ also with regard to the plant parts affected. Some are infected especially in the tassel, others especially in the ear, still others especially at the base of the stalk or on the leaf. An extensive analysis of the genetic behavior of resistance and susceptibility now in progress indicates that a complex condition prevails.

As is generally known, inbred strains of corn are usually inferior in growth and yield to cross-bred strains, and the strains developed in the work at Morgantown are no exception to the rule. None of the immune strains has sufficient vigor and yielding ability to recommend it from this standpoint. Their sole merit lies in their smut resistance. They must be re-invigorated if they are to find a useful place in corn production. In theory this should be possible of accomplishment by means of cross pollination between resistant strains, and attempts to do so are now under way.

Breeding Tobacco for Resistance to Rootrot

Rootrot (Thielavia) is a problem of considerable importance among tobacco growers and although it has been partially solved through the development of resistant varieties, the latter do not yield as well under West Virginia conditions as the non-resistant varieties. R. J. Garber and T. C. McIlvaine, in cooperation with the Office of Tobacco Investigations of the U. S. Department of Agriculture, have attempted to correct the low yield of resistant varieties by breeding with a high-yielding variety. They have crossed Maryland Mammoth, a high-yielding susceptible variety, with two strains of resistant Burley and have secured hybrid strains that combine high yield and resistance. Unfortunately, however, all the hybrids were of poor quality, their market value being only about one-half that of the Burley strains. Although unfortunate in final outcome, the experiments indicate the possibilities of the methods employed and point the way to further trials which are now in progress. In the new experiments Kelly and Pepper, two high-yielding varieties of good quality, well adapted to the Huntington area, have been crossed with the resistant Burleys. It is hoped that strains of the desired characteristics may be isolated from the progeny of these crosses.

FRUITS AND VEGETABLES

Varieties of Fruits Adapted to West Virginia

About 250 varieties of apples, peaches, cherries, pears, plums, nuts, and small fruits are being tested as to their value under West Virginia conditions at Morgantown and at the branch stations at Lakin and Kearneysville by members of the Horticulture department. An interesting phase of the study is the testing of the new color sports of the apple that have lately been introduced. These include three color sports of Delicious, several of Rome and Stayman, and one each of Winesap, Jonathan, and Oldenburg.

Results of these studies up to date have been published in Bulletin 222. It serves as a valuable guide to fruit growers in planning new plantings.

Most Varieties of Apples Self-sterile

In tests on self-sterility of varieties of apples conducted by H. E. Knowlton in the important producing sections of the State practically all have been found to set little fruit when self-pollinated. York seems to be the only variety so far tested that sets sufficiently for a commercial crop when planted by itself. Varieties of the Winesap group will not set any fruit when self-pollinated, because of the impotent pollen produced. These varieties are also cross-sterile from this abortive pollen. Other varieties producing normal pollen are therefore necessary for adequate setting of fruit. De-

sirable combinations of the standard commercial sorts which will insure sufficient fruit setting have also been determined, as for example Jonathan and Delicious or Grimes; York and Rome; and Northwestern and Delicious. Any of the above varieties will fertilize Stayman and Winesap.

Growers are seeing the practical value of these investigations and when making new plantings are no longer setting large blocks of single varieties but are mixing them with the idea of getting adequate cross-pollination.

Better Rootstocks for Apples and Sour Cherries

Propagation of all apple and sour-cherry trees in America is upon seedling rootstocks. These roots vary in vigor, hardiness, resistance to insects and diseases, and soil adaptability, as well as in other factors. These variable roots used as stocks produce trees which differ in size, productivity, length of life, etc. Studies now under way by Leif Verner, in cooperation with the U. S. Department of Agriculture, are aimed at a solution of the problem. The work involves the following method of attack: first, a study of species and types of roots now available for the propagation of apple and sour cherry trees; second, a search for new species, seedlings, and strains that show promise as stocks; third, testing these stocks for insect and disease resistance, congeniality with the various varieties grown commercially, and ease of propagation asexually; and fourth, a study in the orchard of the most promising root stocks when propagated upon the important commercial varieties. Three test orchards for apple stocks have already been planted and a fourth of about 25 acres is to be set out on the University Experiment farm at Kearneysville. This experiment will be one of the most complete and elaborate of any in the United States on this particular problem. In it a dozen or more of the most promising apple stocks (clone and seedling) will be budded this summer to our most important commercial varieties. These trees will be ready to plant out in the spring of 1933. Montmorency cherry on five selections of Mazzard and Mahaleb roots have also been planted on the University Experiment farm.

Potato Seedstock Studies

Studies were made over a period of four years by K. C. Westover and E. N. McCubbin, to determine the effect on yield of the storing of cut potato seedstock. Stored lots cut at two-week intervals during the storage season were compared. The results obtained indicated that only a relatively short time (three weeks at the most) should intervene between the cutting of the seed and the planting operation.

Comparisons of the vigor of the bud and stem ends of the same seed tuber were carried on in 1929 and 1930. Tubers selected from several bags of high-grade seedstock graded to meet U. S. No. 1 grade were sorted according to weight into three groups: (1) 6 to 8

ounces; (2) 8 to 10 ounces, and (3) over 10 ounces in weight. Just before planting time, cyclindrical plugs of the same length were cut from the bud and the stem ends of each tuber and planted in hills in this sequence. The growth and yield data taken do not indicate a real difference in vigor between the bud and stem ends of the tuber, altho there was a tendency for the bud end to produce more stalks per hill.

Trials run during three seasons to determine the effect of green-sprouting Rural potato seed tubers on earliness and yield failed to indicate any marked benefit from this practice.

Experiments to determine the influence on yield of the removal of sprouts from improperly stored seed potato tubers were run for two years. Lots of tubers were compared from which the sprouts had been removed from one to six times during the storage period. The results show quite conclusively that the practice of removing sprouts from improperly stored seed tubers results in greater losses in storage from decay, reduces stand of plants in the field, lowers their vigor, and decreases the yields of No. 1 tubers and the total yields. Tubers which have had the sprouts "rubbed" from them more than once are of questionable value as seedstock.

Strains of Earliana Tomato Earliest at Lakin

In tests conducted at the Lakin Experiment farm in 1929 by K. C. Westover and F. W. Craig, strains of the Earliana tomato were the best-yielding during the early season (to July 25). Burbank was also good. In total yields for the whole season, Bonny Best was highest. World Beater pepper and New York Improved eggplant were outstanding in variety tests of these vegetables.

Preliminary trials were also made in 1930 with early sweet corn, carrots, beets, and early cabbage. The data obtained are, however, considered of little value because of the abnormal weather conditions which existed.

Nitrogen Fertilizers and the Keeping Quality of Apples

Many commercial apple growers claim that fruit from orchards heavily fertilized with quickly available nitrogen fertilizers is being discriminated against by the buyer because of alleged poor keeping quality. In experiments conducted in 1928 and 1929 on Black Twig and Stayman apples by H. E. Knowlton and M. B. Hoffman, apples from nitrated trees kept as well as fruit from trees not so fertilized. Fruit from nitrated trees was poorer in color and somewhat softer in texture, however.

It is believed that the poor reputation of apples on the market from heavily nitrated trees is due principally to three reasons: (1) They have scalded badly in storage because of their poor color. While the value of shredded oil paper in preventing scald has been known for a number of years it has not been used extensively in the East until the last two or three years. (2) In many instances fruit

has been left on the trees until overripe in order to get better color. As a result it has kept poorly in storage. (3) Poorly-colored fruit is lower in dessert quality than well-colored fruit. This is especially true of such varieties as Delicious and Jonathan.

Sulphate of Ammonia Cheapest Nitrogen Fertilizer for Apple Trees

In experiments conducted for the past five years in Jefferson and Pleasants Counties by H. E. Knowlton and M. B. Hoffman, sulphate of ammonia gave as good results as nitrate of soda on apple trees as measured by growth and yield when both were applied several weeks before bloom. When applied at blossoming time nitrate of soda was much superior.

Since sulphate of ammonia is cheaper per unit of nitrogen than other quickly available nitrogenous fertilizers, its use will mean a large financial saving to the apple orchardists of the State. It should be emphasized, however, that this fertilizer gives an acid reaction to the soil; consequently its continued use may be detrimental to leguminous cover crops unless the acidity is corrected by the addition of lime.

Cultural Practises Affect Peach Bud Hardiness

According to studies conducted at Morgantown by H. L. Crane, greater hardiness of peach buds results when trees have stored a large amount of food reserves the summer before. To get this food storage a large and healthy leaf surface should be maintained late in the fall. Moderate dormant pruning, cultivation, applications of nitrogenous fertilizer in the spring, and control of insects and diseases will accomplish this. Fruit thinning should be practiced to prevent overbearing, which depletes the tree's food reserves. Nitrogen content analyses have been made by the department of agricultural chemistry.

These studies are of practical importance to the fruit grower because of the great losses that occur almost annually to peaches, plums, and cherries from low winter temperatures.

Light Pruning Best for Young Fruit Trees

Light pruning of apples, peaches, plums, and cherries for the first few years after planting produces larger trees which come into bearing earlier than trees more heavily pruned, according to experiments conducted by H. L. Crane of the department of Horticulture on the University farm at Morgantown. This light pruning should be continued with sour cherries after the trees come into bearing, but apples and peaches should be pruned more severely if size and color of fruit are to be maintained.

Pruning of Greenhouse Tomatoes

Double-stem tomato plants with the stems tied apart on separate strings yield more than plants with single stems or plants with double

stems tied together, according to studies carried on by A. P. Dye. The single stem plants averaged 11 pounds, the double stem tied together 14 pounds, and the double stem tied apart 18 pounds per plant. Another year's data will be obtained before definite conclusions are drawn. These results will be of interest to greenhouse men since training to a single stem is the common practice.

Results with Paper Mulches on Vegetables Depend on Kind of Crop and Soil

Experiments conducted by K. C. Westover, F. W. Craig, and E. N. McCubbin on paper mulches at Morgantown and at the Lakin Experiment farm have given strikingly different results. On a clay loam soil at Morgantown the paper mulch produced significant differences in growth and yield of tomatoes, peppers, eggplant, string beans, and beets in 1929 as compared with clean cultivation. With peppers, eggplant, and string beans yields were more than doubled.

On a fine sandy loam at Lakin small increases were made, but it is doubtful if the increased yields would pay for the paper. Since these results are only for one year, definite conclusions are not being drawn until further data have been obtained.

Time of Thinning of Elberta Peaches

Late thinning of Elberta peaches (four weeks before harvest) gives as good results when measured by fruit size as thinning done soon after the June drop, according to tests conducted by H. E. Knowlton and M. B. Hoffman.

From the practical standpoint there are many advantages in late thinning. First, less fruit will be removed in late thinning because of the more or less constant dropping that occurs in the interim between the time that fruit is normally thinned and the time of the late thinning (four weeks before ripening). Second, there is opportunity in the late thinning to remove blemished fruits—fruits injured by curculio, hail, limb rubs, etc. Third, if late thinning is as effective as earlier thinning the grower can spread the operation over a longer period, performing it with the regular help without going to the necessity of hiring additional help. Or on the other hand, he may postpone this rather expensive operation until the middle of July, hire more labor, and finish in a few days. This would be an exceptionally good plan to follow in sections where partial or total loss of crop from hail storms in mid-summer is of fairly common occurrence. Thinning done later (three weeks before harvest) may not be as good as earlier thinning, particularly if August is dry.

Lawn Grass Studies

Tests conducted by A. P. Dye for the past three years on kinds and mixtures of grass seeds most suitable for lawns show that the bent grasses and mixtures containing Kentucky bluegrass, redtop, and white Dutch clover are best under conditions at Morgantown. Among

the grasses tested were Velvet, South German, and Rhode Island bent, Kentucky and Canadian bluegrass, New Zealand, fine-leaved, hard, creeping, and sheep's fescue, timothy, wood meadow, crested dogstail, perennial rye grass, redtop, and white Dutch clover. The fescues are difficult to cut, tend to bunch and are unattractive in appearance. The bents stand adverse conditions better than bluegrass but do not make as attractive a lawn.

Greenhouse Carnation Experiments

In handling carnations the common greenhouse practice is to make cuttings in January and February. When rooted they are transplanted to the field until July or August, when they are put in their permanent planting in the greenhouse. A. P. Dye is carrying on experiments to find out if this is the best procedure. Three varieties are being used—White Matchless, Spectrum, and Betty Lou. Cuttings will be made on the first day of December, January, and February. A representative number of each will be planted in their permanent beds in the greenhouse about the middle of May after being in coldframes since April 1, following rooting. Another similar lot will be set in the field until August and then planted in the greenhouse. Records will be kept on quantity and quality of bloom, season of heaviest productivity, and prices obtained throughout the season.

INSECT PESTS

Pistol-Case Bearer a New Problem

The value of research to fruit growing is well illustrated by the work of Edwin Gould and L. M. Peairs with the pistol-case bearer. The insect gets its name from the appearance of its protective case, which resembles a pistol. It feeds on the buds, leaves, and fruit of apple trees. Within the past few years it has developed into a pest of the first magnitude in certain orchards in the eastern section of West Virginia. The entomology staff in the spring of 1929 began a thorough study of the feeding habits and life history of the insect and tested its susceptibility to all the known poisons under a variety of conditions.

The life-history studies finally gave the clue that pointed the way to control. They showed that in hatching, the worm does not expose itself to stomach poisons. It eats directly through the bottom of the egg into the leaf, feeds there a while, and then emerges on the opposite side with its protective case already formed. The only possible hope lay in gassing the worm during the hatching period. Contact insecticides were therefore tested and in numerous trials nicotine proved fully effective. It was found that the efficiency of the nicotine could be increased and the cost lowered when penetrol was added.

Studies continue looking toward discovery of a poison which may be incorporated into the regular spray program, obviating thereby the need of a special spray application.

Orchard Insects

Work on orchard insects has been carried on primarily at Inwood and Kearneysville. The codling moth has received most attention. Studies by L. M. Peairs on a spray program which would eliminate the second brood spray have resulted in a modification of the spray program so that the latest spray may be applied not much later than July 1—about six to seven weeks after the petal-fall spray.

Tests of insecticides to replace arsenate of lead were made. The materials tested included other arsenates, calcium and magnesium, and sodium and calcium fluosilicates, as well as barium carbonate. Best results followed the use of magnesium arsenate, but satisfactory control, not equal, however, to the arsenates, was obtained from the fluosilicates.

Life history studies aiming to establish spraying dates have been continued on codling moth. Apple red-bugs, leaf-roller, bagworm, San Jose scale, flea beetles, and other minor insects have been studied to some extent, mainly as to the degree of control secured by the orchard spray program.

Dusts and Sprays for the Control of Garden Insects

In the control of Mexican bean beetle, now occurring throughout the state, many insecticides have been employed. L. M. Peairs reports that lead arsenate, calcium arsenate, and magnesium arsenate, each one used with lime alone as a carrier, were applied in dust form, and the same materials were applied as sprays. Calcium fluosilicate and sodium fluosilicate were used as dusts, either without dilutions or with the addition of lime or with lime and copper dust. Contact insecticides employed were nicotine, derris, and pyrethrum at various dilutions and with soap as a spreader or with penetrol. Results showed a decided advantage from the use of pyrethrum extract, either alone or with penetrol. This is considered particularly true of "Red Arrow," the great value of this material being to reduce quickly heavy infestations of larvae where early spraying with other materials has been neglected. While it kills larvae most readily, it has a decided killing effect on eggs, pupae, and adults as well. The dilutions permissible with the penetrol activator should make it sufficiently economical to use especially in small plantings.

Biology and Control of the Apple Aphids

At both Inwood and Morgantown it has been found by L. M. Peairs and Edwin Gould that apple aphids, mainly the green aphids, can be killed in the early season with dilutions of nicotine as great as one part to 4000 parts of water, if along with it Penetrol is used

at 1/2% strength. Midsummer tests at Morgantown gave 95-100% kill with one part nicotine to 6000 parts water, and 85-95% with 7500 parts water. Other tests showed similar kill with 4000 parts water and 3/4% Penetrol. Penetrol alone showed little kill.

Strengths less than 1-4000 were ineffective in spring but effective in late June at temperatures of 75° to 90° F. during the period of the tests, indicating that the critical dilution depends somewhat on temperature.

Kill of wholly dormant eggs has been strongly indicated with a pyrethrum—white oil combination. Kill of active forms with very dilute solutions of nicotine—penetrol was secured. With pyrethrum-white oil-penetrol mixtures even greater dilutions—1 to 5000—were effective in a few cases. An accurate measure, however, of the strength of pyrethrum extract was not available.

Relation of Temperature to Insect Life

Soil temperature records from January to May have been kept for several years in the belief that many plant phenomena can be shown to be dependent primarily on soil temperatures rather than on air temperatures. Studies by L. M. Peairs point to the conclusion that soil temperatures alone do not initiate development in the aerial parts of plants, but that, when the air temperatures reach a certain point, the previous soil temperatures have a definite effect on the time required for development. Soil temperatures apparently have a similar effect in the emergence of insects. Temperature in the soil determines the completion of development of forms which winter as pupae. When metamorphosis takes place, some of the insects emerge almost regardless of air temperatures. Many of these do not survive.

The killing power of contact insecticides as influenced by temperature has also been investigated. Different contact sprays act in different ways. For those whose action is dependent upon the absorption of the material by the insect, temperature has a very direct effect on the time factor at least. For those whose action is purely corrosive there seems to be little effect from variations in temperature above the point of freezing of the liquid used. The materials tested were nicotine extracts and two brands of pyrethrum extract.

Miscellaneous Insect Studies

Since concentrated outbreaks of hitherto unimportant insects cannot be foretold, this study has included insects which in some seasons are unusually abundant, as well as insects which have not previously been reported as pests. The work, begun by L. M. Peairs in 1923, has been carried on in various parts of the State.

Two tests using poisoned potatoes as bait in the soil for mole-crickets indicate that the insect will eat and be killed by potatoes poisoned with arsenic and likely by those poisoned with strychnine.

But there is indication that the crickets avoid the strychnine, preferring the unpoisoned potatoes where available. No such avoidance was noted with arsenic-poisoned potatoes.

In the control of the squash vine-borer, four treatments of lower portions of the stems of the vines with nicotine—lead arsenate spray, five to seven days apart, have given good control.

Control of the cucumber beetle was obtained by spraying the entire plant twice with Bordeaux and lead arsenate—once while it was still bushy and once after it had started to run freely. A third spray was applied two or three weeks later.

In gardens in one locality the giant ragweed has been found to harbor 85 percent of the common stalk borer. Destruction of this plant late in June, and burning or feeding it to hogs to obviate survival of the larvae, is recommended.

Magnesium arsenate, with dust or liquid carrier, has proved the best control for blister beetles. The stronger grades of calcium cyanide for dusting purposes have been found unsafe for use on the foliage of most truck crops.

PLANT DISEASES

Apple Varieties Resistant to Cedar Rust

The results of seven years' observations in an experimental orchard of 66 varieties of 8 trees each at Wardensville show that the following eleven varieties are practically immune to cedar-rust infection occurring naturally in that vicinity: Arkansas Black, Delicious, Fameuse, Gravenstein, King David, Kinnard McIntosh, Mann, Northwestern Greening, Starking, and Wolf River. Only occasional "flecks" were found on any of the above varieties.

Thirteen varieties were classed as very highly resistant—Baldwin, Chicago, Dominie, Duchess, Early Harvest, Grimes Golden, Ingram, Martha, Paragon, Mammoth Black Twig, Sweet Bough, Seek-No-Further, and Winesap. Any of the varieties in these two classes could apparently be planted with the assurance that they would be uninjured by cedar rust GYMNOSPORANGIUM JUNIPERI-VIRGINIANAE in the middle Atlantic States, according to C. R. Orton and Anthony Berg, under conditions which are favorable for heavy infections upon Benoni, Rome Beauty, and York Imperial.

Rust-resistant Red Cedars

A field study of the red cedar, JUNIPERUS VIRGINIANA, by Anthony Berg and C. R. Orton, has disclosed its variability with respect to its resistance to GYMNOSPORANGIUM JUNIPERI-VIRGINIANAE in the Shenandoah Valley. In a large natural stand of red cedars some 100 trees have been tagged and notes taken annually for the occurrence of rust galls. Over a period of several years certain trees have shown little or no infection, whereas other trees standing beside them have borne heavy crops of galls annually. The propagation of these resistant types is in progress.

Late Planting of Corn Reduces Rootrot

Studies by L. H. Leonian of the conditions surrounding the infection and development of corn rootrot caused by **Fusarium moniliforme** have shown that the disease is relatively unimportant in West Virginia when infected seed is planted in June, after the soil has become warm and rapid growth of seedlings takes place. The same seed planted in early May produced a poor stand with a higher percentage of infected stalks. The results were approximately the same when healthy seed was planted and the inoculum was introduced into the soil about the roots when the plants were about six inches in height. If warmer temperatures prevail, infected seedlings recover, and no apparent injury can be seen.

Variability in the Corn Rootrot Organism

FUSARIUM MONILIFORME, which causes rootrot, is an extremely variable fungus in pure culture under laboratory conditions. Certain strains isolated from diseased corn plants have dissociated into many variants which differ with respect to sporulation, color, mycelial development, sensitivity to toxic substances, and in pathogenicity. It has been shown by L. H. Leonian that these variants are themselves not permanent and in turn may dissociate into still different forms or may revert to the original type. There is evidence that similar dissociations take place under natural environments and are not to be interpreted as the result of artificial conditions. It is also evident that all such variants or dissociants must be included in our concept of what constitutes the species.

The failure of attempts to synthesize particular variants by mixing together various strains and dissociants indicate the unlikelihood that new variants might arise through such a process.

Russian Watermelon Proves Immune to Wilt

Many strains of watermelon have been tested by E. C. Sherwood for their reaction to the wilt-producing fungus FUSARIUM NIVEUM in heavily infested soil. A Russian variety which possesses the desirable color and shape but is inedible is the only one which has been found to be highly resistant. This was crossed in 1930 with the best commercial varieties grown in the Ohio Valley in an attempt to combine the resistance of the Russian melon with the quality of the commercial varieties.

Two Types of Apple "Measles"

Continued studies by Anthony Berg have led to the conclusion that there are two distinct types of the disease which has heretofore currently passed under the name "measles." One of these types termed PUSTULAR MEASLES exhibits the highest degree of virulence upon Red Astrachan but is also severe upon Maiden Blush, Rome Beauty, and Grimes Golden after infection is established. It has been proved that this type is infectious since the pustules occur only on unprotected twigs of healthy young trees planted under large infected trees. Portions of the stem protected from infection by cellu-

loid cylinders remained free from pustules throughout the season whi'e the same trees showed heavy infections both above and below the cylinders. No infection of new twigs arising from such infected parts takes place in the greenhouse, clearly indicating that this type is not systemic and further that there is some factor absent in the greenhouse which is important in bringing about infection.

Blister measles is a disease which is typical on Starks Delicious variety and is already established in several localities in Northeastern West Virginia. Histological studies show that this disease originates in the primordia of the buds in the region of the pericycle. Grafting experiments have not met with success apparently because of the very low vitality of infected wood.

Bordeaux Mixture More Effective than Copper—Lime Dust in Increasing Potato Yield

Spraying potatoes with Bordeaux mixture seven times at the rate of 200-250 gallons per acre resulted in an increase of more than 100 percent in yield when compared with check plots. Dusted plots showed 35 percent increase over the check. It is evident that copper is more effective in liquid than in dust form in preventing hopper burn, which was the chief malady present in the plots.

Physiological Studies on Phytophthoras

Studies on heterothallism in Phytophthora have been concluded and are now ready to be assembled for publication. Some 85 cultures were mated and 40 of these were found to be heterothallic, 22 representing one sex and 18 the other. Of the remaining 45, some were homothallic, and some showed no sexual reaction in any combination. Thus, one species may consist of strains some of which are homothallic, some heterothallic, and others neutral.

FARM ECONOMICS AND RURAL SOCIOLOGY

Orchard Management in the Eastern Panhandle

A threefold study by A. J. Dadisman of the economics of the apple industry in the Cumberland-Shenandoah region was begun early in 1929 in cooperation with the Pennsylvania and Virginia stations and the Bureau of Agricultural Economics of the U. S. Department of Agriculture. The first part, a survey of the place of apple orcharding in the farm organization of the Eastern Panhandle and surrounding territory, has been reported fully in Technical Bulletin No. 54 of the federal Department, entitled, "Factors influencing the yield of apples in the Cumberland-Shenandoah region of Pennsylvania, Virginia, and West Virginia." The second phase, dealing with markets, costs, and methods of marketing apples, also has been completed and is reported in Technical Bulletin No. 234 of the Department, entitled, "Marketing apples grown in the Cumberland-Shenandoah region of Pennsylvania, Virginia, and West Virginia."

For part III of the study, dealing with the organization and

management of orchards, C. H. Bruce has been employed cooperatively between West Virginia and Pennsylvania, with West Virginia headquarters at Martinsburg. Twenty orchardists in each of these states are visited monthly, and a careful study is being made of such factors as the use of spray machinery, packing, use of fertilizers, and size of business. As a result growers are beginning to study their business from the analysis presented them and are finding ways of reducing costs and increasing returns.

The aim in this piece of research is to unify like studies in three states in which the same practices and problems of orchard management obtain. As more data become available for tabulation and the drawing of conclusions, and through the experience gained by the field workers, each state becomes the beneficiary of similar studies in adjoining commonwealths.

Advantage of Production for Home Consumption Varies with Locality

While nearness to market might be considered of strategic value in the production of staple farm commodities for local consumption, studies by W. W. Armentrout in four major consuming centers of the State point rather in other directions. Inventories of the receipts and shipments of agricultural products in the Charleston, Clarksburg, Beckley, and Wheeling areas were made to determine consumption, along with a survey of the methods of production and distribution of farm products in these areas. The studies cover the period 1923 to 1926, inclusive.

The production of high-quality farm commodities, both perishable and non-perishable, is encouraged in the Charleston area. Soil and climatic conditions are adapted to the production of the usual perishable food commodities, and industrial stability assures a steady demand for such staples as potatoes, milk products, truck crops, fruit, poultry, and meats. It is recommended that the production of quality early potatoes, truck crops, and fruits be increased. Representatives of the Bureau of Agricultural Economics, U. S. D. A., cooperated in the Charleston study. (Bul. 188.)

Farmers in Harrison and nearby counties have a ready home market for practically all their produce, especially potatoes. The present system of distribution of farm produce in Clarksburg is markedly inefficient and unsatisfactory both to farmer and distributor. (Bul. 212.)

Because areas of good farm land in the section are inadequate to produce sufficient farm products to meet local market needs, Beckley and other coal towns in the southern West Virginia coal fields must expect to continue to receive much of their food commodities from distant points. The opening of good roads to the Greenbrier Valley farming section would provide a ready market to the farmers of Summers, Monroe, and Greenbrier counties. The supply of market milk is inadequate for the demand in Beckley, and there would be room for expansion in many types of farm production in the area if suitable land were available. (Bul. 226.)

Farmers in the Wheeling area have an advantage in transportation costs because of nearness to market. Yet it is possible that high production costs cancel this advantage for many commodities. A negligible quantity of potatoes is grown locally, and truck farming appears to be losing in favor. Poultry production for the local trade could be expanded. The growing of apples, grapes, and small fruits is recommended in the area. (Bul. 228.)

Cost, Methods, and Practices of Marketing Livestock

Records of the business transactions of the various county livestock shipping associations in West Virginia for each year of their operation have been collected by W. W. Armentrout. Analysis of the data, including costs of marketing and prices received for various classes of livestock marketed through the associations, freight records of shipments to out-of-state markets, and records of livestock prices received by some 2000 farmers in private sale during 1928 and 1929, is in process.

Systems of Livestock Farming in West Virginia and Southwestern Virginia

In 1928 W. W. Armentrout, in cooperation with field workers from Virginia Polytechnic Institute and the Bureaus of Agricultural Economics and Animal Industry of the U. S. Department of Agriculture, obtained records on the organization and operation of 150 livestock farms in the state. The Department of Agriculture is tabulating and analyzing the data.

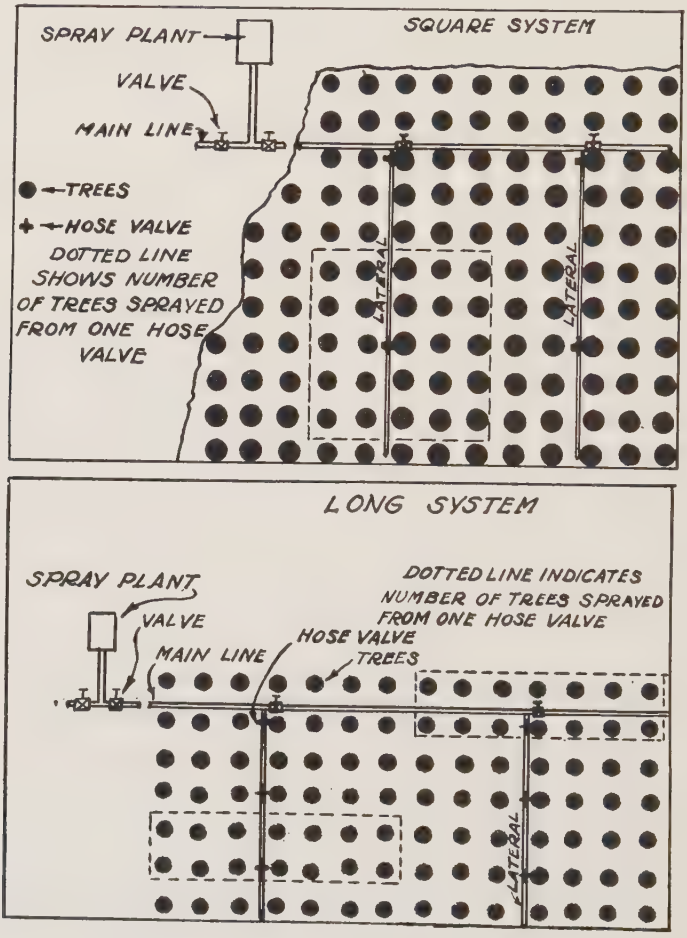
The Fine-Wool Sheep Industry

In October, 1929, Pennsylvania, Ohio, West Virginia, and the U. S. Department of Agriculture began a study of the cost of producing fine-wool sheep in the three states. Sixty-five cooperators were obtained by R. O. Stelzer in Brooke, Ohio, Wetzel, Tyler, and Marion counties. Each of these farmers was visited three times during the year. These visits included taking an inventory of sheep, equipment, and feed; bringing the sheep, feed, and pasture records up to date; and making up the lamb, wool, feed, and labor record. The object of the study, which is pursued by the department of farm economics and the Agricultural Extension Division, is to determine for the territory involved the cost of production, returns, methods of handling, trends in production, the place, and the outlook for fine-wool sheep on northern West Virginia farms.

Hydrant Spray Systems

A project begun by F. D. Cornell, Jr., in 1927 and now pursued in cooperation with the department of plant pathology has as its object a detailed study of the stationary spraying systems in the State, including installation details and costs, costs of operation, mechanical efficiency of equipment, friction losses in pipe lines, pressures, etc., as well as comparison of costs and efficiency of stationary systems with the common methods of tank spraying under simi-

lar conditions. A detailed survey has been made of all stationary spray systems in the State, and complete cost records have been obtained for most of these. In addition cost data and other comparable information were obtained on 20 orchards using the portable system of spraying during the same seasons. Results of the study are in process of publication.



Methods used in piping orchards

A stationary spray system also has been installed on the University Experiment farm at Kearneysville. This plant will furnish opportunity for further study of the mechanical efficiency of this type of spray equipment. The entire study continues with emphasis on mechanical tests and measurements with the view to adding useful information to the available knowledge concerning the stationary plant for spraying operations.

Practical Farm Building Plans for West Virginia

In order to develop a series of workable plans of the essential buildings and equipment for farms under West Virginia conditions, a project was begun by F. D. Cornell, Jr., in 1926 in the hope that greater interest in better farm buildings could be stimulated and that marked improvement would eventually be brought about in the arrangement, construction, and equipment of new structures. Many requests for such information had been received by the Station for help concerning the planning, erecting, and equipping of farm buildings.

The first publication in the series, "Buildings and equipment for the dairy farm," appeared in January, 1928; the second, "Buildings and equipment for the livestock farm," was published in November, 1928. Since then work has been undertaken for a publication on storage buildings for the farm. Data have been assembled on common storage of apples under West Virginia conditions, and text material on potato and machinery storage also has been prepared.

The Status of 4-H Work

In order to determine the types of existing young people's organizations in the rural sections of West Virginia, along with their objectives, activities, and accomplishments, as well as to determine the value of these groups in developing a satisfactory rural life and in promoting a permanent and effective agriculture, a state-wide study was inaugurated in 1926 by T. L. Harris, rural sociologist, in cooperation with the Division of Farm Population and Rural Life of the Bureau of Agricultural Economics, U. S. D. A.

The scope of the study includes an analysis of the structure, functions, and influences of 341 clubs in 39 counties; case-studies of a county in which 4-H work has made steady progress, a county in which the work has declined, and a single club which is in some respects outstanding, in other respects average or below; an analysis of the effects of club experience in the socializing of personal character; appraisals of club work by supervisors and by parents; and an estimate of the strength and weakness of the movement as found in the State. A published report of the study, completed in 1929, is pending.

HOME ECONOMICS

Standardization of Preserves and Jelly

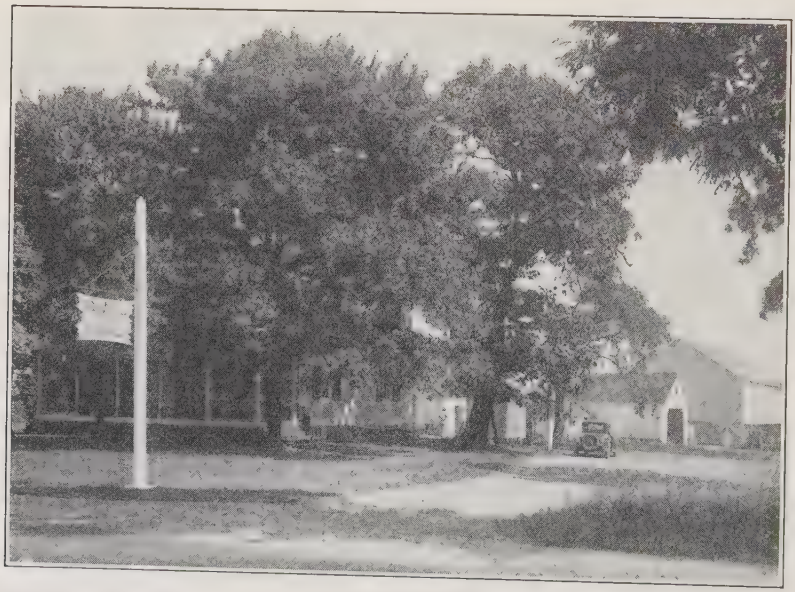
Fruit obtained in the vicinity of Morgantown within a few hours after picking was used by Hazel Cameron and Ruth B. Burns in tests to determine a satisfactory method for cherry and blackberry preserves and blackberry jelly, and to utilize a surplus of fruit in certain parts of the State where a satisfactory market was not available for the fresh fruit. Determinations, reported in Bulletin 234,

included the sugar-to-fruit ratio, optimum final temperatures, cooking jelly to weight, effect of adding pectin solution, consistency and yield of jelly made with the addition of various amounts of unripe berries, and tests of color, syrup, flavor, and texture of the final product.

Under-nourished Rats May Provide Clue to Cause of Common Cold in Humans

Investigation of some of the chemical factors which underlie respiratory infections occurring in rats kept on diets lacking in vitamin A has been undertaken as a nutrition problem by Hazel Cameron. Large numbers of albino rats are being raised on Vitamin-A free diets, with control animals on the same diet plus Vitamin A. The aim is to determine whether or not there is any relation between the common cold in human beings and the respiratory infections of rats as described, since good results in preventing colds have been reported from the use of codliver oil, which is known to protect rats from respiratory infections.

The sterol cholesterol is being studied in this experiment to see if it is increased in the blood before or after the onset of infection; or whether it is increased in the adrenal gland, which is normally a storehouse for this substance. Changes in the weight and the water content of this gland are also being investigated as having a possible bearing on the apparent sterol content. Cholesterol determinations have been made by the department of agricultural chemistry.



Residence and buildings on University Experiment Farm, Kearneysville

Agricultural Experiment Station Staff

JOHN R. TURNER, Ph. D., LL. D., President of the University
F. D. FROMME, Ph. D. ..... Dean and Director
GERALD JENNY, M. S., Agricultural Editor .... JOHN C. JOHNSTON, Chief Clerk

AGRONOMY AND GENETICS

R. J. Garber, Ph. D.
Agronomist and Geneticist

E. P. Deatrick, Ph. D.
Associate Agronomist

W. H. Pierre, Ph. D.
Associate Agronomist

T. C. McIlvaine, Ph. D.†
Assistant Agronomist

M. M. Hoover, M. S.
Assistant Agronomist

G. G. Pohlman, Ph. D.
Assistant Agronomist

H. K. Rowley, M. S. Agr.**
Seed Analyst

W. S. Ligon, B. S. Agr.
Graduate Assistant

ANIMAL HUSBANDRY

E. A. Livesay, D. Sc.
Animal Husbandman

C. V. Wilson, M. S.
Assistant Animal Husbandman

J. H. Longwell, M. A.
Assistant Animal Husbandman

J. H. Rietz, D. V. M.**
Associate Veterinarian

R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman

E. N. Moore. D. V. M.**
Assistant Veterinarian

C. Q. Williams, B. S.
Graduate Assistant

S. R. Johnson, B. S.
Graduate Assistant in Veterinary Science

CHEMISTRY

R. B. Dustman, Ph. D.
Agricultural Chemist

C. E. Weakley, Jr., M. A.
Assistant Chemist

L. P. Hansen, Ph. D.
Assistant Chemist

T. B. Leith, M. S.**
Assistant Chemist

I. J. Duncan, B. S.
Assistant

A. H. Van Landingham, B. S.
Graduate Assistant

DAIRY HUSBANDRY

H. O. Henderson, Ph. D.
Dairy Husbandman

L. M. Thurston, Ph. D.
Assistant Dairy Husbandman

K. S. Morrow, M. S.
Assistant Dairy Husbandman

L. F. Sutton, B. S. Agr.‡
Assistant Dairy Husbandman

R. A. Ackerman, M. S. Agr.
Graduate Assistant

H. C. Olson, B. S.
Graduate Assistant

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist

W. E. Rumsey, B. S.**
State Entomologist

Edwin Gould, B. S. Agr.
Assistant

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist

F. D. Cornell, Jr., M. S.
Assistant Farm Mechanician

W. W. Armentrout, M. S.
Assistant Farm Economist

R. O. Stelzer, B. S.
Assistant

C. H. Bruce, B. S.
Assistant

HOME ECONOMICS

Rachel H. Colwell, M. A.
Home Economist

Hazel C. Cameron, M. A.
Research Specialist in Nutrition

HORTICULTURE

H. E. Knowlton, Ph. D.
Horticulturist

K. C. Westover, M. S. Agr.
Assistant Horticulturist

F. W. Craig, M. S. Agr.**
Assistant Horticulturist

Leif Verner, M. S.
Assistant Horticulturist

M. B. Hoffman, M. S.
Assistant

E. N. McCubbin, M. A.
Assistant

A. P. Dye, M. S. Agr.
Assistant

PLANT PATHOLOGY

C. R. Orton, Ph. D.
Plant Pathologist

Anthony Berg, M. S.
Associate Plant Pathologist

L. H. Leonian, Ph. D.
Associate Plant Pathologist

F. J. Schneiderhan, M. S.††
Associate Plant Pathologist

E. C. Sherwood, M. S.
Assistant Plant Pathologist

R. G. Brown, B. S. Agr.
Graduate Assistant

POULTRY HUSBANDRY

Horace Atwood, M. S. Agr.
Poultry Husbandman

T. B. Clark, B. S. Agr.
Assistant

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Experiment Farm, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.
††In charge of the University Experiment Farm, Kearneysville, W. Va.

STAFF CHANGES

Appointments

F. D. Fromme, dean and director; R. A. Ackerman, assistant in dairy husbandry; C. H. Bruce, assistant in farm economics; F. W. Craig, assistant horticulturist; I. J. Duncan, assistant in agricultural chemistry; R. S. Glasscock, assistant in animal husbandry; Edwin Gould, assistant in entomology; Gerald Jenny, agricultural editor; E. N. McCubbin, assistant in horticulture; K. S. Morrow, assistant dairy husbandman; C. R. Orton, plant pathologist; W. H. Pierre, associate agronomist; F. J. Schneiderhan, associate plant pathologist; R. O. Stelzer, assistant in farm economics; L. M. Thurston, assistant dairy husbandman.

Resignations

E. L. Anthony, dairy husbandman; H. L. Crane, associate horticulturist; L. E. Dills, assistant in entomology; D. R. Dodd, assistant agronomist; P. A. Eke, assistant farm economist; N. J. Giddings, plant pathologist; H. F. A. North, assistant in agronomy and genetics; T. E. Odland, associate agronomist; L. C. Shriver, assistant in agricultural chemistry; G. M. Trout, assistant dairy husbandman.

PUBLICATIONS

ABSTRACTS OF BULLETINS

Bul. 221. Cooperative Buying in West Virginia. Paul A. Eke. General. 56 pp. March, 1929. This publication comprises detailed recommendations concerning the organization, management, business policies, financing, and accounting of cooperative purchasing associations. A complete copy of the West Virginia Cooperative Marketing Act of 1923 is included.

Bul. 222. Varieties of Fruits for West Virginia. H. E. Knowlton. General. 40 pp. March, 1929. The origin of varieties of the commoner tree fruits grown in West Virginia is given along with descriptions of the characteristics of fruit and tree. Fruits discussed include the apple, crab apple, peach, sweet, sour, and Duke cherries, pear, and plum. How to avoid sterility in planting is also indicated.

Bul. 223. A Study of the Time Factor in Egg Production. Horace Atwood. Technical. 12 pp. October, 1929. Statistical interpretation as to mean length of intervals between successive egg-layings, and standard deviation of intervals in cycles of varying numbers of eggs, is given for 172 White Leghorns trapped hourly for one month during their first laying year.

Bul. 224. The Cost of Raising Dairy Cows in West Virginia. Paul A. Eke. General. 12 pp. November, 1929. An investigation was made of the costs incurred in raising heifers for herd replacements among 128 dairymen owning purebred, grade, or native stock in ten dairy sections of the State. Total costs are analyzed into their various items. Differences are noted in costs between typical dairy sections such as large city fluid milk, small city milk and cream, and creamery sections, as well as between spring and fall calves and between purebred, grade, and native heifers.

Bul. 225. The Relative Value of High-Grade and Low-Grade Calves Marketed as Two-Year-Old Steers. E. A. Livesay. General. 12 pp. November, 1929. Twenty-four steer calves, twelve of them high-grade calves of Hereford breeding, the other twelve of nondescript breeding, were carried through two winter feeding and two summer feeding periods. Further division was made into four lots of six each. One lot of good to choice and one lot of common calves received linseed oilmeal in their rations; the other lots (one good to choice and one common) received cottonseed meal. Costs were kept of feeds and pasture, and upon slaughter the carcasses were compared for evidences of superiority of well-bred over low-grade stock.

Bul. 226. Adjusting Agricultural Production and Distribution in the Beckley Area to Meet Home Market Demands. W. W. Armentrout. General. 20 pp. January, 1930. This bulletin is the third of a series of reports dealing with the consumption of food commodities in West Virginia cities and with the production of these commodities in adjacent farming territory. Other areas previously studied were the Charleston and Clarksburg areas.

Bul. 227. Soybeans for Silage and for Hay. T. E. Odland. General. 24 pp. February, 1930. No farm crop introduced into West Virginia has become of such importance in so short a time as have soybeans. This bulletin presents the results of experiments in which corn and soybeans were grown alone in various ways and in several combinations for silage purposes. Soybeans also were grown alone and in combination with other crops for hay. Tests also were conducted with soybeans sown at various rates and at different dates for hay.

Bul. 228. Adjusting Agricultural Production and Distribution in the Wheeling Area to Meet Home Market Demands. W. W. Armentrout. General. 28 pp. February, 1930. A record of the quantity of certain food commodities which passed through the Wheeling market, of the sections of the country from which the commodities came, and of the transportation charges is given in this, the fourth of a series of studies of consumption of farm products in the larger cities of West Virginia and of production in the agricultural sections surrounding them.

Bul. 229. Cream Line Studies of Market Milk. G. Malcolm Trout. Technical. 20 pp. March, 1930. The growing importance of the market milk industry in West Virginia, together with the introduction of much modern machinery, prompted a study of the effect of agitation and pumping on the creaming ability of market milk. Determinations also were made of the critical temperatures at which pumping had the most harmful effect upon the depth of cream layer appearing at the top of the bottle of milk.

Bul. 230. Growth Studies with Swine. J. H. Longwell, H. O. Henderson, and W. M. Insko, Jr. Technical. 24 pp. March, 1930. Experiments are described seeking to determine the effects of feeding butterfat, margarine fats and oils, and a basal ration free from the known sources of the fat-soluble, growth-promoting vitamin upon the growth and development of pigs.

Bul. 231. The Effect of Feeding Different Amounts of Calcium and Phosphorus upon the Growth and Development of Dairy Animals. H. O. Henderson and C. E. Weakley, Jr. Technical. 56 pp. March, 1930. Thirty-two grade Holstein heifer calves were divided into four groups of eight calves each. Each group was fed a ration as similar to the other rations in its digestible crude protein and total nutrient content as it was practical to obtain. The chief difference between the rations fed was in the calcium and phosphorus content. The effects of the ration were studied by weighing and measuring the animals at weekly intervals and by analyzing the blood for inorganic phosphorus and calcium, the bones for moisture, extractable material, and ash, and the ash for calcium and phosphorus.

Bul. 232. Wintering Dairy Heifers by Means of the Self-Feeder. H. O. Henderson and E. L. Anthony. General. 20 pp. April, 1930. Two groups of dairy heifers were used during each of three trials. One group was fed during the winter months a ration as near its requirements as was practicable, while the animals in the other group were fed all the roughage they would consume and were given access to a hopper which was kept filled with cornmeal, wheat bran, and linseed oilmeal. All were turned on pasture in season, and returned to the stable late in November. Each group was weighed and height at withers was measured every two weeks during the winter months and at monthly intervals during the summer months. A record was kept of the amount of feed consumed by each group.

Bul. 233. The Relationship between the Number and Weight of Eggs and Body Weight of Leghorn Fowls During the First Three Years of Production. Horace Atwood and T. B. Clark. Technical. 20 pp. April, 1930. Investigation into the normal variation in the fecundity of fowls at different ages, and of the changes taking place in the weight of the eggs and in the weight of the fowls from year to year, is reported on the basis of records made by 178 birds during the first and second years and by 165 birds which remained at the end of the third year of the experiment.

Bul. 234. Standardization of Cherry and Blackberry Preserves and Blackberry Jelly. Hazel Cameron and Ruth B. Burns. Technical. 24 pp. June, 1930. Investigation was undertaken to determine a satisfactory method for making cherry and blackberry preserves and blackberry jelly, with the aim of utilizing a surplus of fruit existing in certain parts of the State where a satisfactory market was not available for the fresh fruit.

Bul. 235. Pasture Experiments. T. E. Odland, C. V. Wilson, H. O. Henderson, and E. P. Deatrick. General. 32 pp. June, 1930. The pasture crop is the most important crop in the State. Experiments were planned to obtain information on the improvement of permanent pastures of the type that is too steep to plow. Treatments on the dairy and the livestock farms of the University at Morgantown consisted of manure, manure and superphosphate, superphosphate, and nitrate of soda. A lime strip extended across one-half of all plots. Three seed mixtures also were compared, and disking was contrasted to no-cultivation.

LIST OF CIRCULARS

Cir. 50. Crop Rotations for West Virginia. D. R. Dodd, R. J. Garber, and T. E. Odland. 24 pp. September, 1928.

Cir. 51. Better Seed Corn—Growing, Selecting, Storing, Testing. R. J. Garber and M. M. Hoover. 16 pp. August, 1929.

Cir. 52. Raising Dairy Calves and Heifers. James V. Hopkins and H. O. Henderson. 24 pp. October, 1928.

Cir. 53. Buildings and Equipment for the Livestock Farm. F. D. Cornell, Jr. 56 pp. November, 1928.

Cir. 54. Orchard Spraying in West Virginia. E. C. Sherwood and L. M. Peairs. 32 pp. March, 1929.

Cir. 55. Blackberry Jelly, Blackberry Jam, and Cherry Preserves. Hazel Cameron. 12 pp. May, 1930.

ABSTRACTS OF SCIENTIFIC PAPERS

No. 30: F. E. Chidester and W. M. Insko, Jr. Influence of thyroid extract and iodine on growth and development. I. With a standard basic diet. Am. Nat. 62: 554-558. 1928. Rats and rabbits were placed on a standard basic diet, and certain lots were given glucose, KI, and thyroid extract, respectively. Glucose retarded weight decrease otherwise occurring under heavy iodine feeding. Fat deficiency in the diet was evident, even in the presence of sufficient minerals, and the vitamins. Iodine influence on metabolism was demonstrated.

No. 31: F. E. Chidester, A. G. Eaton, and W. M. Insko, Jr. Influence of desiccated thyroid and iodine on growth. II. With a standard acid diet. Am. Nat. 63: 239-247. 1929. Twenty-eight rats and six rabbits were used in experiments on the influence on growth of thyroid extract and iodine with a standard acid diet. In the rabbits, glucose apparently protected the animals somewhat from the usual iodine effects. In the rats, low dosage of thyroid favored pregnancies in all cases and did not cause resorption of the young. Minute doses of thyroid induced growth of bones and increased weights. Glucose, administered with the iodine, accelerated this gain.

No. 46: T. E. Odland. The inheritance of a quantitative character, length of rachilla, in an oat cross. W. V. U. Scient. Asso. 2(3): 57-64. Oct. 1928. The factor determining the inheritance of pubescence of rachilla is believed to be in the same linkage group as one or more of the factors determining the length of rachilla.

No. 55: E. P. Deatrick. Watering potted soil kept under microbiologically controlled conditions. Science 68: 114-115. Aug. 1928. When soil in large pots is to be used, some method must be found to cover the soil with a cotton seal which will not be wetted by the moist soil. This has been accomplished by placing an inch mulch of very coarse gravel over the soil.

No. 56: L. H. Leonian. Studies on the variability and dissociations in the genus Fusarium. Phytopath. 19: 753-868. Sept. 1929. A certain specific line of behavior persists throughout all of the strains and variants of a given fungus species. The path of the species may run in a zigzag line, but it does not exceed the specific orbit.

No. 57: R. J. Garber and M. M. Hoover. The relation of smut infection to yield in maize. Jour. Am. Soc. Agron. 20: 735-746. July 1928. Selfed lines of maize may be isolated which differ sharply with respect to resistance to smut. Corn plants infected with smut in the tassel only yielded on the average more than did plants of similar genetic constitution but free from smut.

No. 58: H. E. Knowlton. Factors affecting fruit setting in the apple. W. V. U. Scient. Asso. 2(3): 46-56. Oct. 1928. A variety of apple is "born" with a certain genetic complex, upon which the various environmental factors play.

No. 59: E. P. Deatrick. Reduction of soil nitrates during the growth of soybeans. Jour. Am. Soc. Agron. 20: 947-958. Sept. 1928. In following soybeans with winter wheat it is advisable to plant soybeans of shorter growing period so as to allow for longer intervals for nitrification in the soil before the planting of wheat. Nitrates in soils under maturing soybeans are very low.

No. 60: R. J. Garber. The nature and significance of mutations in present-day breeding methods. Sci. Agr. 9: 133-143. Nov. 1928. Among field crops mutations of economic value appear so rarely that one would hardly be justified in basing a system of breeding upon their chance occurrence.

No. 61: R. J. Garber, N. J. Giddings, and M. M. Hoover. Breeding for disease resistance with particular reference to smut of oats. Sci. Agr. 9: 103-115. Oct. 1928. Breeding plants for resistance to disease offers one of the most satisfactory means of controlling numerous plant diseases.

No. 62: Horace Atwood. Observations concerning the time factor in egg production. Poult. Sci. 8: 137-140. Mar. 1929. The longer the cycle the shorter are the intervals between the laying of successive eggs. The intervals between egg-layings about the middle of the cycles are shorter than the intervals at either extremity. The shorter average intervals are usually associated with the more prolific layers.

No. 63: M. M. Hoover. Wheat-rye hybrids. Jour. Hered. 20: No. 4. April 1929. Fultz 7 wheat was the seed parent, and Rosen rye No. 3 the pollen parent. The hybrid plants resembled wheat rather closely, although they were intermediate in most plant characters.

No. 64: E. P. Deatrick and Clarence Dorman. Determination of the fineness of marl. Soil Sci. 27: 121-122. Feb. 1929. Determinations made according to the standard method—that of calculating the percentages of material of certain finenesses from the weights of the thoroughly dried material held on the screens after thorough shaking—are inaccurate.

No. 65: Horace Atwood. The variation in the weight and number of eggs and the weight of White Leghorn fowls during the first two years of production. Poult. Sci. 8: 51-55. Nov. 1928. Decreases from first to second year were 20.1 percent for number of eggs and 14.4 percent for weight of eggs. Increase in average weight of eggs the second year was 7.36 percent, and increase in weight of birds during second year was 15.3 percent compared to weight during first year.

No. 66: Horace Atwood and Thomas Clark. Further studies on factors influencing the weight of eggs. Poult. Sci. 8: 193-197. May 1929. Kamala should not be given while birds are in full production, since undesirable effects may result in at least some cases.

No. 67: A. G. Eaton, W. M. Insko, Jr., G. P. Thompson, and F. E. Chidester. The influence of suprarenal cortex and medulla on the growth and maturity of young (White Leghorn) chicks. Am. Jour. Phys. 88: 187-190. March 1929. Fifty White Leghorn chicks when twelve days old were divided into three groups and placed under experiment for eleven weeks to determine the influence of feeding desiccated suprarenal medulla and cortex, in addition to a standard or balanced ration. Males receiving desiccated suprarenal cortex matured more rapidly, as indicated by the weights of the testes. Their body weights, like those of the females in the cortex group, nearly equalled the controls. Chicks fed suprarenal medulla grew less rapidly than the controls or the cortex group, and the weight of the testes fell far below controls and cortex group.

No. 68: F. E. Chidester and A. G. Eaton. The influence of arsenic, ferrous sulphate, and copper sulphate on rats furnished a Vitamin A-free diet with iron added. Proc. Soc. Exp. Biol. 26: 141-142. 1928. Arsenic, iron, and copper in minute doses seem less effective than the combination of iron and iodine previously shown by the writers to be of benefit in vitamin-A deficiency.

No. 69: F. E. Chidester, A. G. Eaton, and G. P. Thompson. The influence of a modified Fowler's solution of arsenic on rats receiving vitamin A-free diet with iron iodide added. Proc. Soc. Exp. Biol. 26: 143-144. 1928. Fowler's solution of arsenic in doses of 0.379 mgm. daily was used in combination with iodide of iron in an experiment to determine their effect on vitamin-A deficient rats. Rapid declination in weight indicated the probable digestive disturbance due to arsenic in the presence of iron.

No. 70: T. E. Odland and R. J. Garber. Tests of native and foreign clover strains in West Virginia. Jour. Am. Soc. Agron. 21: 355-360. March 1929. Clover strains of Italian origin were worthless for West Virginia conditions, and from other European countries and Chile, generally undependable. Uniformly good results were obtained with strains from Ohio, Wisconsin, Michigan, Idaho, and Tennessee.

No. 71: R. J. Garber and M. M. Hoover. Natural crossing between plants of hybrid origin in oats. Jour. Agr. Res. 38: 647-648. June 1929. Among 15 black-seeded plants growing among forms supposed to be homozygous for white seed, 14 segregated for seed color in the next generation, showing conclusively their hybrid origin. One of the plants bred true for black seed, and therefore it probably was the only one of this group whose presence was due to an accidental mixture.

No. 72: R. J. Garber, N. J. Giddings, M. M. Hoover. Transgressive segregation for susceptibility to smut in an oat cross. Jour. Agr. Res. 39: 953-962. Dec. 1929. Gopher, moderately susceptible, was crossed with a highly resistant if not immune Black Mesdag. Resistance to smut is apparently dominant and controlled by a single main factor difference. There is

apparently a linkage between the black-color gene and a modifying factor which brings about transgressive segregation for susceptibility.

No. 73: K. C. Westover. The effect on yield of sprout removal from potato seed tubers. Proc. Am. Soc. Hort. Sci. 25: 53-57. 1928. The practice of removing sprouts from improperly stored potato seedstock increases the loss in storage from decay, reduces the stand of plants in the field and lowers their vigor, and decreases the yield of prime tubers and the total yield.

No. 74: Hazel C. Cameron. Thyroid feeding and high room temperature. Science 69: 576. May 1929. A temperature of 96° F. was sufficient to cause death in normal rats as well as in those suffering from vitamin-A deficiency.

No. 76: F. E. Chidester, A. G. Eaton, and G. P. Thompson. The influence of desiccated suprarenal cortex and medulla on the growth and maturity of young rats. Am. Jour. Phys. 88: 191-194. 1929. Desiccated suprarenal cortex induces earlier sexual maturity in young female rats than does suprarenal medulla.

No. 77: L. H. Leonian and H. L. Geer. Comparative value of the size of Phytophthora sporangia obtained under standardized conditions. Jour. Agr. Res. 39: 293-311. Aug. 1929. The size factor cannot be of primary importance in taxonomy. Hartley's organisms Nos. 8, 36, and 121 are sufficiently different from all others to merit further study in their native habitat to determine whether they should be described as new species.

No. 78: N. J. Giddings, H. A. Allard, and B. H. Hite. Inactivation of the tobacco mosaic virus by high pressures. Phytopath. 19: 749-750. Aug. 1929. High pressures were effective in destroying or inactivating the virus of tobacco mosaic.

No. 79: Paul A. Eke. Results of a regional replanning study in the mountains of West Virginia as illustrative of the scope, methods, and practical results of such studies: The community as a unit in land utilization. Jour. Farm Econ. 11: 412-421. July 1929. Forest areas should be located by state authority in non-agricultural areas. Public guidance should be provided in relocating the residents. Forest areas should be purchased by county, state, or federal government wherever private or corporate ownership fails to provide economic forest management.

No. 80: R. B. Dustman and L. C. Shriver. The chemical composition of Andropogon virginicus and Danthonia spicata at successive growth stages. Jour. Am. Soc. Agron. 21: 561-567. May 1929. The early growth of both grasses shows high protein and low fiber content compared to the later growth stages. Reasonably early, close, and continuous grazing during the spring and early summer months is advisable.

No. 81: H. E. Knowlton. Some recent results in apple sterility studies. Proc. Am. Soc. Hort. Sci. 26: 62-64. 1929. Stayman will not fertilize Delicious, but York, Grimes, and Golden Delicious are good fertilizers for it. Stayman, Winesap, and Mammoth Black Twig are not only self-sterile but of little value as pollenizers for other varieties because of the impotent pollen they produce.

No. 82: M. B. Hoffman. The use of performance records in laying out a raspberry fertilizer experiment. Proc. Am. Soc. Hort. Sci. 26: 203-207. 1929. Trustworthy results may be expected from the use of a 30-foot single-row plot.

No. 83: K. C. Westover. The relative vigor of the bud and the stem ends of the same potato seed tuber. Proc. Potato Asso. Amer. 16th Ann. Meet.: 101-105. Dec. 1929. There seems to be no real difference in vigor between the bud and the stem ends of the same seed potato.

LIST OF OTHER TECHNICAL PAPERS

F. E. Chidester, A. G. Eaton, and G. P. Thompson. The influence of minute doses of iodine and iron on growth of rats furnished a vitamin-A free diet. Science: 68 (1766): 432. November 2, 1928.

F. D. Cornell, Jr., and H. L. Crane. Stationary spray systems in West Virginia orchards. Agric. Eng. 10, No. 5. May, 1929.

A. J. Dadisman. Factors influencing the yield of apples. W. Va. Acad. Sci. 2. Aug. 1928.

H. E. Knowlton and M. B. Hoffman. Size of peaches as affected by time of thinning. (Prel. Rept.) Proc. Am. Soc. Hort. Sci. 25: 277-279. 1928.

E. A. Livesay. An experimental study of hybrid vigor or heterosis in rats. Genetics 15: 17-54. January, 1930.

J. H. Longwell. Buckwheat middlings as a protein supplement for growing and fattening swine. Proc. Amer. Soc. An. Prod. 1928: 98-100.

LIST OF CURRENT PROJECTS

CURRENT EXPENSE FUND

Number	Title	Department
CE-5	Miscellaneous Chemical Investigations	Chemistry
CE-6	Oat Investigations	Agronomy
CE-7	Soybean Investigations	Agronomy
CE-8	Oat Smut	Agronomy and Plant Pathology
CE-9	Cover Crop Experiments	Agronomy and Dairy
CE-10	Pasture Fertilization Studies	Agronomy, Dairy, and Office of Forage Crops Investigations, U. S. D. A.
CE-11	Crop Rotation Experiments	Agronomy
CE-13	Effect of Soybeans on Crop That Follows	Agronomy
CE-14	Comparison of the Production of Baby Beef, Two-Year-Old and Three-Year-Old Steers	Animal Husbandry
CE-15	Forage Crops and Winter Rations for Swine	Animal Husbandry
CE-16	Line Breeding vs. Outcrossing	Dairy Husbandry
CE-17	A Study of Roots as a Feed for Dairy Cows	Dairy Husbandry
CE-18	A Study of the Different Varieties of Pastures for Milk Production	Dairy Husbandry
CE-20	Cost of Raising Dairy Heifers in West Virginia	Dairy Husbandry
CE-21	A Growth Study with Ayrshire Cattle	Dairy Husbandry
CE-22	A Comparative Study of the Microflora of Raw and Pasteurized Grade-A Milk	Dairy Husbandry
CE-23	The Control of Infectious Abortion (Brucella Abortus Infection) in Cows by Herd Management and Testing	Animal Husbandry and Dairy Husbandry
CE-24	Miscellaneous Entomological Investigations	Entomology
CE-25	Orchard Insects	Entomology
CE-26	Supply, Methods of Marketing, and Consumption of Food in West Virginia Cities, and Agricultural Production in Nearby Territory	Farm Economics
CE-27	Practical Farm Building Plans for West Virginia	Farm Economics

Number	Title	Department
CE-29	The Status, Trends, Place, and Outlook of the Fine-Wool Sheep Industry in the Northern Part of West Virginia	Farm Economics and Extension Division
CE-30	Physiological Effect of Pruning Fruit Trees	Horticulture
CE-31	Potato Investigations	Horticulture
CE-32	Project Covering Miscellaneous Work	Horticulture
CE-35	The Physiology of Phytophthoras	Plant Pathology
CE-37	A Study of the Proper Incubating Temperature for the Eggs of the Domestic Fowl in Incubators of the Cabinet Type	Poultry Research
CE-38	Alfalfa Investigations	Agronomy
CE-39	A Study of the Manufacture of Sweet-Curd, Rennet-Coagulated Cottage Cheese	Dairy Husbandry
CE-40	Sweet Clover Investigations	Agronomy and Agricultural Chemistry
CE-41	A Study of the Water Consumption of Dairy Animals	Dairy Husbandry
CE-43	A Study of the Value of Oats as a Preventive of Vitamin A and D Deficiencies in Pigs	Animal Husbandry and Agricultural Chemistry
CE-44	Crop Responses to Various Fertilizers	Agronomy and Horticulture
CE-98	A Comparison of the Milk-Producing Qualities of Soybean Hay and Alfalfa Hay	Dairy Husbandry
CE-100	Steer Feeding	Animal Husbandry

SALES FUND

Number	Title	Department
S-1	Line Breeding vs. Outcrossing	Reymann Memorial Farms, Dairy Husbandry, and Bureau of Dairy Industry, U. S. D. A.
S-2	Hay Tests of Forage Plants, Alone and in Mixtures	Agronomy

ADAMS FUND

Number	Title	Department
A-1	Relation of Temperature to Insect Life	Entomology
A-2	Sterility Studies with the Apple	Horticulture

Number	Title	Department
A-4	Hardiness Studies of the Fruit Buds of the Peach	Horticulture and Chemistry
A-5	Apple Rust	Plant Pathology
A-6	The Relation between Fusarium Moniliforme and the Corn Plant	Plant Pathology
A-7	Factors Affecting the Weight of Hen Eggs	Poultry Research
A-8	The Time Factor in Egg Production	Poultry Research

HATCH FUND

Number	Title	Department
H-1	Wheat Investigations	Agronomy
H-2	Corn Investigations	Agronomy
H-3	Dusts and Sprays for the Control of Garden Insects	Entomology
H-4	Variety Tests of Fruit Trees	Horticulture
H-5	Cultural Treatments and Fertilizers for Fruits	Horticulture
H-7	Dusting and Spraying for the Control of Diseases	Plant Pathology
H-8	Variety and Strain Studies of Vegetables	Horticulture

PURNELL FUND

Number	Title	Department
P-1	Breeding Tobacco for Resistance to Root-Rot and High Yield	Agronomy and the Office of Tobacco Investigations, U. S. D. A.
P-2	Soil Acidity and Plant Growth	Agronomy, Agricultural Chemistry Coop. in part
P-4	Growth Studies with Young Pigs	Animal Husbandry
P-5	The Effect of Breed of Sire on the Production and Quality of Lamb	Animal Husbandry and Bureau of Animal Industry, U. S. D. A.
P-7	Fattening Two-year-old Steers on Grass with and without a Grain Supplement	Animal Husbandry, and Bureau of Animal Industry, U. S. D. A.
P-8	The Effects of Low-Calcium and Low-Phosphorus Rations on Growing Dairy Heifers	Dairy Husbandry and Agricultural Chemistry
P-9	Biology and Control of the Apple-Infesting Aphids	Entomology
P-10	The Biology and Control of the Pistol Case Bearer	Entomology
P-11	Cost, Methods, and Practices of Marketing Livestock	Farm Economics and U. S. D. A.

Number	Title	Department
P-12	A Study of Orchard Management and of the Place of Orchards in the Farm Organization of the Apple Section of Eastern West Virginia	Farm Economics, U. S. D. A., Virginia, and Pennsylvania
P-13	A Study of the Costs, Efficiency, and Management of Hydrant Orchard Spraying Systems in West Virginia	Farm Economics and Plant Pathology
P-14	The Economic Utilization of Surplus Food Products with Special Reference to the Problems of the Home	Home Economics
P-15	A Study of the Relation of the Lipoids, particularly Cholesterol, to the Incidence of Respiratory and Middle-Ear Infections Occurring on Vitamin A Deficient Diets	Home Economics
P-16	The Improvement of Root Stocks for Apple Trees	Horticulture
P-17	Studies on the Storage Qualities of Fruits of the Apple as Affected by the Culture and by the Fertilizer Treatments Given the Orchard	Horticulture
P-18	Fusarium Wilt of Watermelon	Plant Pathology and Agronomy (Genetics)
P-19	A Study of Apple "Measles"	Plant Pathology
P-20	A Study of Variability in Composition of Different Skeletal Parts of Experimental Animals	Agricultural Chemistry
P-22	Paper Mulches vs. Clean Culture for Vegetable Crops	Horticulture
P-23	Constituents of Milk that Contribute to the Flavor of Dairy Products	Dairy Husbandry
P-24	Causes for Poor Quality of Cream Transported in Less Than Carlots	Dairy Husbandry
P-159	Young People's Organizations as a Factor in West Virginia Rural Life	Rural Sociology

TABLE OF CONTENTS

PAGE

DIRECTOR'S STATEMENT ---- 3

Previous Reports ---- 3

Current Research in Review ---- 4

Cooperation with Other Research Agencies ---- 5

Field Days ---- 7

New Land and Buildings ---- 7

Map Showing Distribution of Research in State ---- 8

Research an Investment, not Expenditure ---- 9

REPORTS OF RESEARCH ---- 10

Agricultural Chemistry ---- 10

Animal Husbandry ---- 11

Dairy Husbandry ---- 16

Poultry Husbandry ---- 23

Crops and Soils ---- 24

Fruits and Vegetables ---- 31

Insect Pests ---- 36

Plant Diseases ---- 39

Farm Economics and Rural Sociology ---- 41

Home Economics ---- 45

STAFF LIST ---- 47

STAFF CHANGES ---- 48

PUBLICATIONS ---- 48

Abstracts of Bulletins ---- 48

List of Circulars ---- 51

Abstracts of Scientific Papers ---- 51

List of Other Technical Papers ---- 55

LIST OF CURRENT PROJECTS ---- 56

Bulletin 245 December, 1931

UNIVERSITY OF ARIZONA
JAN 9 1932
LIBRARY

Seed-Borne Parasites

A Bibliography

BY C. R. ORTON

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

Agricultural Experiment Station Staff

JOHN R. TURNER, Ph. D., LL. D., President of the University
F. D. FROMME, Ph. D. .....Dean and Director
GERALD JENNY, M. S., Agricultural Editor....JOHN C. JOHNSTON, Chief Clerk

AGRONOMY AND GENETICS

R. J. Garber, Ph. D.
Agronomist and Geneticist
E. P. Deatrick, Ph. D.
Associate Agronomist
W. H. Pierre, Ph. D.
Associate Agronomist
T. C. McIlvaine, Ph. D.†
Assistant Agronomist
M. M. Hoover, M. S.
Assistant Agronomist
G. G. Pohlman, Ph. D.
Assistant Agronomist
H. K. Rowley, M. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, D. Sc.
Animal Husbandman
C. V. Wilson, M. S.
Assistant Animal Husbandman
J. H. Longwell, M. A.
Assistant Animal Husbandman
R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman
J. H. Rietz, D. V. M. **
Associate Veterinarian

CHEMISTRY

R. B. Dustman, Ph. D.
Agricultural Chemist
Chas. E. Weakley, Jr., M. A.
Assistant Chemist
T. B. Leith, M. S.**
Assistant Chemist
I. J. Duncan, B. S.
Assistant in Agricultural Chemistry
A. H. Van Landingham, M. S.
Assistant in Agricultural Chemistry

DAIRY HUSBANDRY

H. O. Henderson, Ph. D
Dairy Husbandman
L. M. Thurston, Ph. D.
Associate Dairy Husbandman
G. A. Bowling, M. S.
Assistant Dairy Husbandman
L. F. Sutton, B. S. Agr.‡
Assistant Dairy Husbandman
R. A. Ackerman, M. S. Agr.
Assistant in Dairy Husbandry

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist
W. E. Rumsey, B. S.**
State Entomologist
Edwin Gould, B. S. Agr.
Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist
F. D. Cornell, Jr., M. S.
Assistant Farm Mechanician
W. W. Armentrout, Ph. D.
Assistant Farm Economist
R. O. Stelzer, M. S.
Assistant in Farm Economics

HOME ECONOMICS

Rachel H. Colwell, M. A.
Home Economist
Hazel C. Cameron, M. A.
Research Specialist in Nutrition

HORTICULTURE

H. E. Knowlton, Ph. D.
Horticulturist
K. C. Westover, M. S. Agr.
Assistant Horticulturist
F. W. Craig, M. S. Agr.**
Assistant Horticulturist
Leif Verner, M. S.
Assistant Horticulturist
E. N. McCubbin, M. A.
Assistant in Horticulture
A. P. Dye, M. S. Agr.
Assistant in Horticulture
W. H. Childs, M. S.
Assistant in Horticulture

PLANT PATHOLOGY

C. R. Orton, Ph. D.
Plant Pathologist
Anthony Berg, M. S.
Associate Plant Pathologist
L. H. Leonian, Ph. D.
Associate Plant Pathologist
F. J. Schneiderhan, M. S.††
Associate Plant Pathologist
E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

T. B. Clark, B. S. Agr.
Assistant in Poultry Research

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Experiment Farm, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.
††In charge of the University Experiment Farm, Kearneysville, W. Va.

Seed-Borne Parasites—A Bibliography

by C. R. ORTON*

ASSEMBLING OF DATA on seed-borne parasites was begun by the compiler more than fifteen years ago, but the impetus to an organized effort to prepare something comparable to a cosmopolitan list of such organisms was furnished by the Advisory Board of the American Phytopathological Society, which appointed a committee of three to engage in this task. Two preliminary mimeographed lists were prepared and sent to phytopathologists in the United States and Canada as well as to workers in foreign countries. These lists must have been of special interest, for since the date of the last circulation the compiler has received numerous requests for them from many parts of the world. It has been this insistent and continued demand for these data which has led to a continued effort in bringing together the appended list which, while acknowledged to be incomplete and in many ways unsatisfactory, is a basis for further work upon this important phase of phytopathology.

EARLY HISTORY OF SEED TRANSMISSION OF PARASITES

The idea that plant parasites were associated with the seed dates back at least two hundred years. In 1733 Jethro Tull *(1)* recorded the observations of farmers near Bristol, England, that seed wheat salvaged from sea water was free from bunt. This record is also one of the first milestones in seed disinfection and led to the use of salt-water steeps which were in vogue until the 19th century. It was not until 1755 that proof of seed carriage of a plant parasite was presented when Tillet *(2)* published his studies on wheat bunt, which were later corroborated and elaborated by Gleichen *(3)* and Tessier *(4)* who demonstrated that wheat plants become infected with bunt only when the spores of Tilletia are present on the planted grains.

---

*The compiler was assisted by M. F. Barrus, Department of Plant Pathology, Cornell University, and M. T. Munn, Division of Botany, New York (Geneva) Agricultural Experiment Station, in the preparation of the early lists of seed-borne parasites which were prepared by this group working as a committee of the American Phytopathological Society.

Thanks are especially due Dr. J. Ramsbottom, Curator, British Museum, London, England; Dr. H. W. Wollenweber, Biologische Reichsanstalt, Dahlem-Berlin, Germany; and Dr. G. H. Pethybridge, Ministry of Agriculture, Harpenden, Herts, England, for the help they rendered in circulating a preliminary list to their associates and obtaining additions and suggestions which have been very helpful in making this work more complete. Many others throughout the world have cooperated in furnishing special data and to these the compiler acknowledges his indebtedness.

(1) Horsehoeing Husbandry, etc., London.

(2) Dissertation sur la cause qui corrompt et noircit les grains de ble dans les epis, etc., Bordeaux.

(3) Auserlesene mikrosk. Entdeckungen. 1781.

(4) Traite des maladies des grains. Paris 1783; Moyens eprouves pour preserver les froments de la carie. Avignon, 1786.

A century elapsed before the first proof of seed transmission by a parasite other than a smut was presented. Frank *(5)* demonstrated that the fungus causing bean anthracnose was seed-borne by means of the mycelium, which grows through the seed pod into the seed coat during its early maturing period. The first bacterial plant pathogen proved to be seed-borne was *Bacterium phaseoli,* which was demonstrated by Beach *(6)* to be carried within the seed. Since that time the evidence that plant parasites are commonly carried with the seed has been steadily accumulating. That nematodes were transmitted in this manner was proved by Maize *(7)* in 1906 in the case of *Tylenchus dipsaci,* although the presence of this nematode in the seed had been established by Kuehn *(8)* in 1858.

ECONOMIC IMPORTANCE OF PARASITES WHOLLY OR LARGELY SEED-BORNE

A study of the following tabulated data taken from "The Plant Disease Reporter" of the United States Department of Agriculture clearly indicates the importance of this manner of distributing plant diseases. It is also helpful in showing the importance of seed disinfection, which is very effective in controlling certain cereal diseases. While these data apply to the United States only it is reasonable to assume that they are comparable to conditions in other countries where these diseases occur and where control measures are comparably applied.

Estimated annual losses to certain crops in the United States from seed-borne parasites during the nine-year period 1919-27

Crop and Disease	Bushels (000 omitted)									
	1919	1920	1921	1922	1923	1924	1925	1926	1927	Ave.
Wheat bunt	10,219	14,088	10,988	5,798	11,308	26,038	16,633	33,786	28,888	17,527
Loose smut	17,863	9,754	7,889	10,484	9,964	9,800	8,465	8,373	7,359	9,994
Total	28,082	23,842	18,877	16,282	21,272	35,838	25,098	42,159	36,247	27,521
Barley stripe	1,898	786	1,041	1,172	1,369	1,981	3,647	2,415	2,751	1,896
Loose smut	1,369	1,385	764	1,481	1,875	1,573	2,064	2,186	2,559	1,695
Covered smut	1,868	1,992	694	1,903	990	1,146	5,757	3,557	2,509	2,268
Total	5,135	4,163	2,499	4,556	4,234	4,700	11,468	8,158	7,821	5,859
Oats. Loose and covered smuts	39,238	40,143	35,810	29,378	35,278	52,907	51,267	49,852	51,359	42,804
Beans										
Anthracnose	354	155	49	163	392	...	114	...	38	180
Bacterial blight	808	141	1,040	647	895	...	674	...	330	647
Total	1,162	296	1,089	810	1,287	...	788	...	368	827
Cotton*										
Anthracnose	468	579	154	62	229	172	22	188	144	224
Angular leaf-spot	187	213	213	59	632	443	292	561	138	304
Total	655	792	367	121	861	615	314	749	282	528

*Bales.

(5) Ber. deutsch. Bot. Gesell. *1*: 31. 1883.
(6) N. Y. (Geneva) Agr. Exp. Sta. Bul. 48. 1892.
(7) Bul. Soc. Bot. France IV: 6: 53 (Sess. Extra) LXXV - LXXVII. 1906.
(8) Zeit. Wiss. Zool. *9*: 129-137. 1858.

Thus it is seen that the economic losses occasioned by these few seed-borne parasites, selected because of the availability of data, are enormous. With wheat alone an approximate average of 27,500,000 bushels could be added annually to the crop in the United States by treatment which would cost from two to five cents per bushel for the seed planted, the cost depending upon the method and materials used.

DISTRIBUTION OF IMPORTANT PLANT DISEASES BY SEED

A study of seed transmission clearly shows that certain pathogens are distributed almost wholly in this manner, while other pathogens may be transmitted in a number of ways in addition to being seed-borne. The smuts of cereals and grasses, *Bacterium phaseoli, Colletotrichum lindemuthianum, Helminthosporium gramineum, Nematospora phaseoli, Ascochyta pisi,* and *Tylenchus dipsaci* are examples of pathogens which are wholly or largely disseminated by seeds. Such organisms as *Fusarium subulatum, Gibberella saubinetii, Mycosphaerella brassicicola, Phoma lingam, Septoria pisi, Sclerospora graminicola, Phytophthora phaseoli, Albugo tragopogonis,* and certain mosaics such as those of beans and other legumes are quite invariably seed-borne but are often transmitted in other ways.

Such pathogens as those included in the first group could be almost wholly restricted in their further distribution by seed selection and disinfection.

MANNER IN WHICH PATHOGENS ARE SEED-BORNE

The manner in which plant pathogens exist with seeds is variable. A modification of Dorogin's *(9)* outline is as follows:

1. Pathogens composed of sclerotia which become mixed with the seed but not attached to it: e. g.,
   Sclerotinia trifoliorum and *Sclerotium rolfsii.*
2. The pathogen forms a mummified structure composed of seed or fruit and parasite in an intimate relation: e. g., the pseudo-sclerotium of *Sclerotinia vaccinii, S. carunculoides* and *Claviceps purpurea,* and the mummies of *Tylenchus tritici.*
3. The pathogen forms a fructification on the surface of the seed: e. g., *Phoma lingam* on crucifers, *Botrytis cinerea* on corn.
4. Spores or other reproductive stages of the pathogen are carried mechanically on the surface of the seed; e. g., *Tilletia laevis, Urocystis occulta,* and many other smuts; *Fusarium lycopersici* and many other species of this genus; *Polyspora lini* on flax. Some bacterial pathogens are undoubtedly carried in this manner.
5. Bacterial organisms, certain viruses, and the mycelium of pathogenic fungi are localized within the seedcoat, or in the reproductive organs of the seed: e. g., *Ustilago tritici* and other smuts with similar manner of

(9) Notwendigkeit die Samen auf die Pilzparasiten bei Samenkontrolle zu untersuchen. Ann. Essai Semences 5: 19-27. 1927.

seed infection; *Gibberella saubinetii* in wheat and other cereals; *Diplodia zeae* and *Fusarium moniliforme* in corn seed; and a host of other fungous parasites such as *Bacterium phaseoli, B. stewartii,* and numerous other bacterial pathogens including the mosaic of beans and other legumes.

Chen *(10)* has made a study of certain internal parasites of agricultural seeds and Heald *(11)* and Gardner *(12)* have discussed this subject in connection with the more general topic of dissemination of fungi and bacteria.

NATURE OF SEED-BORNE PARASITES

Many sorts of organisms may be carried with seeds as outlined above, but the most important from the standpoint of disease transmission are bacteria, fungi, nematodes, and insects. In this treatment the last group has been omitted, although there is no doubt that the insects present an important phase of the problem. The nematodes have been included as is customary in phytopathological literature.

Judging from the list of seed-borne organisms, any of the bacterial phytopathogens are likely to be transmitted by seed. In fact from the rapidly accumulating data it appears that every bacterial disease of plants should be considered potentially dangerous from the angle of seed transmission.

While there is no proof that Myxomycetes or Chytrids can be transmitted by seed, nevertheless it is evident that representatives of most of the other important groups of fungi are capable of being seed-borne. For instance, representatives of the Zygomycetes and Oomycetes are present in the list. In the Ascomycetes there are many representatives which are seed-borne in their asexual stages, but few if any are known to be transmitted by ascospores with the possible exception of the yeast-like fungi, Nematospora, etc. Several rusts (Uredinales) are known to be seed-borne and probably this group will be much more extensively represented when studied more fully from this standpoint. The smuts (Ustilaginales) are abundantly represented and it is not exaggerating to state that practically all of the grass smuts are seed-borne as well as many of the smut fungi attacking other host plants. Only comparatively few of the Hymenomycetes have been shown to be transmitted in this manner: e. g., Corticium (Rhizoctonia) and Coprinus.

Of the nematodes which may be seed-borne it appears that the two species of Tylenchus, viz., *T. tritici* and *T. dipsaci,* are quite generally seed-infesting and therefore naturally transmitted in this manner. Other plant-inhabiting nemas should be studied from this standpoint.

The remaining group of diseases represented in the list are those attributed to viruses of the mosaic type. Proof is lacking that any yel-

(10) Maryland Agric. Exp. Sta. Bul. 240: 81-110. 1920.
(11) The dissemination of fungi causing disease. Trans. Am. Micros. Soc. *32*: 1-29. 1913.
(12) Mode of dissemination of fungous and bacterial diseases of plants. Mich. Acad. Sci. Rept. *20*: 357-423. 1918.

lows type of virus disease is seed-borne, and many tests with aster and peach yellows indicate that these diseases are rarely if ever transmitted in this manner. That the ease of mechanical transmission of a virus is not a criterion of seed transmissibility is evidenced by tobacco mosaic, which is one of the most readily transmitted viruses of plants. Repeated tests by different workers have failed to show any indications of seed transmission.

COMMERCIAL ASPECT OF SEED TRANSMISSION OF PLANT PARASITES

Man is the chief agent responsible for the spread of plant pathogens by seed or other reproductive organs. During the developmental stages of crop introduction, from regions where seed-borne parasites have become established, seeds have been shipped into new regions where the parasites carried with them have found suitable environments for development. This movement has been world-wide and has resulted in the distribution of such parasites to many new regions where they had not previously existed. This condition may be said to have reached its climax in the case of the smuts of small grains, bean anthracnose, and some few other diseases, but there are many other serious seed-borne plant diseases which have not yet reached some of the world's important agricultural regions. There are undoubtedly many important pathogens in foreign countries which have not yet reached the United States. Some of these which are known to be seed-borne are marked with a star (*) in the subtended list.

Every means possible should be utilized in preventing this harmful distribution of destructive parasites. Galloway *(13)* has plainly outlined the problem and pointed out the remedy so far as general policies apply. The compiler *(14, 15, 16)* has frequently urged seedsmen and others concerned to take a more active interest in this problem of seed transmission of parasites, and some progress has been made. Munn *(17)* has ever been insistent that the seed analyst should take cognizance of this problem in the routine of seed germination tests, and we hope that some day this will become a regular part of the seed analyst's work in the United States as it has in Holland through the studies of Miss Doijer *(18)*. Seed introduction is now attended in part by seed disinfection and testing, and some seedsmen are practicing seed treatment. Many farmers are applying seed disinfection and this practice is gradually increasing—a procedure which will have considerable effect upon the spread of dangerous parasites through seeds. The importance of giving attention to these factors in seed production was outlined by

(13) Some of the broader phytopathological problems in their relation to foreign seed and plant introduction. Phytopathology *8*: 87-97. 1918.
(14) Seed borne diseases. Am. Seed Trade Assoc. Proc. *40*: 74-82. 1922.
(15) Seed borne parasites. A general consideration of the problem. Science *59*: 539-546. 1924.
(16) Seeds as carriers of disease. Jour. N. Y. Bot. Garden *27*: 54-63. 1926.
(17) The seed analyst's responsibility with reference to seed-borne diseases. Proc. Assoc. Off. Seed Analysts *11*: 31-35. 1919.
(18) Infecties van Zaaizaden in verschillende jaren. Rijksproefs v. Zaadcontrole Wageningen 1925.

Norton and Leathers *(19)* in 1918, and their publication has no doubt been influential in the organization of certified seed production associations which are just beginning to realize the importance of the parasite factor in their efforts.

If the efforts of seed producers, seed tradesmen, seed analysts, the manufacturers of seed disinfectants, and official agencies could be brought into cooperation on this problem it would take but a short time to reduce the losses through seed-borne parasites to a point where this phase of disease control would be adequately handled. To these efforts should be added those of the research worker who will find in the problem of seed-borne parasites an interesting and little-developed field which would be very productive in bringing forward the data needed to show how the multifarious parasites exist within and upon seeds.

EXPLANATION OF THE SUBTENDED LIST

The list of seed-borne parasites which follows has been gathered from many sources over a considerable period. Throughout the work the word "seed" is used in the popular sense to connote the various botanical entities containing an embryo and used for propagation. No attempt has been made to include the numerous and important pathogens which are borne upon or within vegetative organs such as bulbs, corms, tubers, cuttings, etc. These would perhaps constitute an equally large number and it seems best to reserve such a task for a later date. Such a list is being prepared at least in part at Dahlem-Berlin under the direction of Dr. H. Pape, to whom the compiler is indebted for several additions to this list.

There has been no attempt in this work to include a full bibliography in connection with the specific parasites. Only those which seemed to be the most important references are included. In many cases the earliest reference to the seed-borne nature of the parasite and one or more later references which more fully established the case have been included. There are included also a number of pathogens which critical workers would call "doubtful cases". The wisdom of this may be questioned but it seems well to include them with the statement frankly made that full proof is lacking. Most if not all of these examples will eventually be shown properly to belong in the category of seed-borne parasites. It has also seemed advisable to include a few specific cases of parasites which have been proved by competent workers to be seed-borne, but which have not been published to date. These are included with the consent of the worker and in a few instances represent important additions. The compiler takes all responsibility for errors and other shortcomings which he has attempted to reduce to a minimum but which undoubtedly may exist in a work of this nature.

---

(19) Conditions detrimental to seed production. Md. Agr. Exp. Sta. Bull. 216: 175-226. 1918.

SEED-BORNE PARASITES*

African Millet *(Eleusine coracana)*

**Ustilago eleusines* Kulk. *Smut*

Narasimhan, M. J. Mysore Dept. Agr. Rept. 1922-1923: pt. 2, 13-15. Controlled by Cu So_4, Cu So_4 and lime, or by formaldehyde treatment of seed.

Agropyron

(See quackgrass, wheat grass, and western rye grass)

Alfalfa *(Medicago sativa)*

Alternaria sp. *Seed-rot*

Peglion, V. Staz. Sper. Agr. Ital. *36:* 198-204. 1903.

Stewart, F. C. New York (Geneva) Agr. Exp. Sta. Bul. 305: 398-400. 1908. Described by Peglion in Italy as *Alternaria tenuis* and is claimed to have a perfect stage, *Pleospora alternariae* Griff. & Gib. Stewart is uncertain whether the disease he describes is the same or not, but the trouble is prevalent in commercial alfalfa seed from many sources and is certainly an internal organism. Its association with any field disease is undetermined.

Bacillus lathyri Manns & Taub. *Streak*

Taubenhaus, J. J. Delaware Agr. Exp. Sta. Bul. 106: 62-69. 1914. The disease is found also on *Phaseolus vulgaris, Pisum sativum, Soja (Glycine) max, Trifolium pratense,* and *Vicia faba.*

Colletotrichum trifolii Bain. *Anthracnose*

Bain, S. M., & S. H. Essary. Tenn. Agr. Exp. Sta. Bul. 75: 1906. This disease is thought by the authors to be seed-borne but actual proof is lacking, though the appearance of the disease on seedlings grown in greenhouse may be considered *prima facie* evidence. Primarily important on red clover.

Peronospora trifoliorum deBary. *Downy mildew*

Campbell, Carlo. Ann. di Bot. *15:* 283-284. 1922. Seed from Argentina grown in Italy developed the disease.

Tylenchus dipsaci Kuehn. *Alfalfa-stem nematode*

Orton, W. A., & G. H. Godfrey. Mo. Bul. Dept. Agric. Calif. *12:* 299. 1923. Carried with the seed and may be eliminated by steam treatment.

Alsike Clover *(Trifolium hybridum)*

Bacillus lathyri Manns & Taub. *Streak* (See alfalfa)

Bacterium trifoliorum Jones, Will., Wolf, & McCull. *Bacterial leaf-spot*

Jones, L. R., M. M. Williamson, F. A. Wolf, & L. McCulloch. Jour. Agr. Res. *25:* 471-490. 1923. Not proved to be seed-borne, but floral parts become infected and there is every opportunity for seed infection to take place. Attacks red, white, crimson, and other species of clover. Artificial infection was successful on lima bean and velvet bean.

Mosaic (Virus)

Dickson, B. T. McDonald College Tech. Bul. 2: 82, 86. 1922.

Alyssum (See sweet alyssum)

Arrhenatherum (See oat grass)

---

*Species preceded by an asterisk (*) are not reported from the United States.

ARBOR VITAE *(Thuja occidentalis)*

Keithia thujina Durand. *Leaf blight*

Pethybridge, G. H. Quart. Jour. Forest. *13:* 93-97. 1919. Field evidence indicates that this parasite may have been introduced to British Isles from America on or with seed, since the trees as such are not imported. Professor A. Henry of Dublin, Ireland, expressed a similar opinion in letter to the compiler, October 29, 1924.

ARDISIA CRISPA

**Bacillus foliicola* Miehe. *Bacterial "symbiont"*

Miehe, H. Jahrb. f. Wiss. Bot. *53:* 1-54. 1913. Invariably present in the seed and considered necessary for healthy development of seedlings.

ASCLEPIAS CURASSAVICA = MILKWEED

AVENA = OATS

BARLEY *(Hordeum vulgare)*

Bacterium cerealinum (Gentner) Elliott. *Bacteriosis*

Gentner, G. Centralbl. f. Bakt. *50:* 428-441. 1920. Seed treatment with one percent formaldehyde reduces but does not eliminate the disease. Also attacks rye and wheat.

Bacterium translucens Jones, Johns., & Reddy. *Bacterial blight*

Jones, L. R., A. G. Johnson, & C. S. Reddy. Jour. Agr. Res. *11:* 625-644. 1917.
——— ——— & ——— Phytopath. *5:* 69. 1917. Attacks also *H. distichum* and *H. hexastichum.*

**Cladosporium herbarum* (Pers.) Link. *Black-end disease*

Perfect stage is *Mycosphaerella tulasnei* Janc. (See RYE)

Claviceps purpurea (Fries) Tul. *Ergot*

Sclerotia are carried with the seed.

Colletotrichum graminicolum (Ces.) Wils. *Anthracnose*

Selby, A. D., & T. F. Manns. Ohio Agr. Exp. Sta. Bul. 203: 1909.

Gibberella saubinetii (Mont.) Sacc. *Seedling blight* and *"scab"* (See WHEAT)

Helminthosporium californicum Mack. & Pax. *Rusty blotch*

Behaves like *H. sativum* on seed, according to correspondence with W. W. Mackie, Univ. of California, College of Agriculture.

Helminthosporium gramineum Rabenh. *Stripe*

Ravn, F. K. Bot. Tidsskr. *23:* 101-321. 1900. Mycelium in seed coats and in the seed. Perfect stage shown to be *Pleospora trichostoma* by Diedicke. (Centralbl. Bakt. II, *9:* 317-329. 1902; *11:* 52-59. 1903.)

Helminthosporium sativum. P. K. & B. *Spot blotch*

Evans, N. S. Phytopath. *12:* 34. 1922. Attacks rye also. Seed disinfection with certain organic mercury compounds is effective.
Pammel, L. H., C. M. King, & A. L. Bakke. Iowa Agr. Exp. Sta. Bul. 166: 78-90. 1910.

Helminthosporium teres Sacc. *Net blotch*

Ravn, F. K. Bot. Tidsskr. *23:* 101-321. 1900. Mycelium in seedcoats and in seed. Perfect stage said to be *Pyrenophora teres* (Died.) Drechs.

Rhynchosporium secalis (Oud.) Davis. *Leaf spot* (See RYE)

**Tilletia pancrea* Bub. & Ran. *Covered smut*

Adachi, M. Jour. Plant Protect. *11:* 275-280. 1924.
———— Ann. Phytopath. Soc. Japan *1.* 1925.

Ustilago Hordei (Pers.) Kell. & Sw. *Covered smut*

Brefeld, O. Die Brandpilze II: *11.* 1895.
Clinton, G. P. Ill. Agr. Exp. Sta. Bul. 57. 1900.
Herzberg, P. Zopfs Beitr. Phys. Morph. Organ. *5:* 1-36. 1895.
Kellerman, W. A., & W. T. Swingle. Kans. Agr. Exp. Sta. Rept. *2:* 213. 1890.

Ustilago nuda (Jens.) Kell. & Sw. *Loose smut*

The Agr. Gazette & Jour. Council of Agr. Tasmania *4:* 92-95. 1896.
Brefeld, O. Brandpilze IV: *13.* 1905.
F. Council of Agr. of Tasmania 1897.
Hecke, L. Zeitschr. f. Landw. Versuch. Oesterr. *7:* 59-64. 1904.
———— Ber. Deutsch. Bot. Gesell. *23:* 248. 1905.

Bean *(Phaseolus vulgaris)*

Alternaria sp. Relation to field disease undetermined

Chen, C. C. Maryland Agr. Exp. Sta. Bul. 240: 95. 1920.

**Ascochyta phaseolorum* Sacc. *Leaf spot*

Seed-borne in Japan, according to Prof. T. Matsumoto *fide* Dr. H. W. Wollenweber.

Bacillus lathyri Manns & Taub. *Streak* (See ALFALFA)

Bacterium flaccumfaciens Hedges. *Bacterial wilt*

Burkholder, W. H. Phytopath. *16:* 915-927. 1926. Also occurs on lima bean.
Hedges, Florence. Science *55:* 433-434. 1922.

Bacterium medicaginis phascolicola (Burk.) Link & Hall. *Halo blight*

Burkholder, W. H. Phytopath. *16:* 919. 1926. The same organism causes "halo blight" of Kudzu, lima, and scarlet runner beans.
Higgins, B. B. Ga. Agr. Exp. Sta. Bul. 161: 1-20. 1930. Experiments indicate seed disinfection to be quite effective.

Bacterium leguminiperdum (von Oven) Stevens. *von Oven's bacterial disease*

v. Oven, S. Centralbl. f. Bakt. II. *16:* 69-74. 1906. Infection of pods extends to seeds. Attacks also Lupinus, *Lycopersicum esculentum,* and *Pisum sativum.*

Bacterium phaseoli EFS. *Bacterial blight*

Beach, S. A. N. Y. (Geneva) Agr. Exp. Sta. Bul. 48: 318. 1892.
———— N. Y. (Geneva) Agr. Exp. Sta. Rept. 1892: 553-554. 1893.
Halsted, B. D. N. J. Agr. Exp. Sta. Rept. 1892: 283-286. 1893.
Whetzel, H. H. Cornell Agr. Exp. Sta. Bul. 239: 210-212. 1906.
Zaumeyer, W. J. Phytopath. *19:* 96. 1929.
Organism may pass through vascular system into developing seed or from dorsal suture of pod into the funiculus and through raphe into seed coat. Entrance of bacteria may also be made through micropyle when the bacteria invade the cavity of seed pod. Cotyledon infection generally occurs during germination of seed. Reported hosts are: *Dolichos lablab, Phaseolus aconitifolius, P. acutifolius latifolius, P. angularis, P. aureus, P. lunatus, P. lunatus macrocarpus, P. multiflorus, P. mungo, P. vulgaris, Soja (Glycine) max, Stizolobium deeringeanum. Strophostyles helveola,* and *Vigna sinensis.* Seed treatment with mercury compounds reduces the disease but does not eliminate it.

**Bacterium phaseoli* var. *fusca* Burk.

Burkholder, W. H. N. Y. (Cornell) Agr. Exp. Sta. Mem. 127: 22-29. 1930. Similar to the common bacterial blight but differing in certain cultural re-

specs and in host plants. Attacks *P. vulgaris, P. lunatus,* and *P. coccineus.* Reports disease from Switzerland and states that Hedges isolated what appears to be this organism from bean seed imported from South America.

Bacterium puerariae Hedges = *B. medicaginis phaseolicola*

See Hedges, Florence. Phytopath. *20:* 140. 1930.

Bacterium vignae Gard. & Kend. *Bacterial spot of cowpea* (See COWPEA)

Attacks: *Phaseolus angularis, P. limensis, P. limensis* var. *limenanus, P. lunatus macrocarpus,* and other leguminous hosts.

Bacterium vignae var. *leguminophila* Burk.

Burkholder, W. H. N. Y. (Cornell) Agr. Exp. Sta. Mem. 127: 1-88. 1930. Artificial infection was obtained on *Phaseolus lunatus, Dolichos lablab, Pueraria hirsuta, Vigna sinensis, V. sesquipedalis, Soja (Glycine) max,* and *Vicia faba.* This organism has a wider range of hosts than *Bacterium vignae.*

**Bacterium (Phytomonas) viridiflava* Burk.

Burkholder, W. H. N. Y. (Cornell) Agr. Exp. Sta. Mem. 127: 1-88. 1930. Found in Switzerland and England. Artificial infection obtained on *Phaseolus coccineus, P. lunatus, Dolichos lablab, Vigna sinensis, Pueraria hirsuta,* and *Soja (Glycine) max.*

Colletotrichum lindemuthianum (Sacc. & Magn.) Briosi & Cav. *Anthracnose*

Beach, S. A. N. Y. (Geneva) Agr. Exp. Sta. Rept. *1892:* 283-286. 1893.
Frank, A. B. Ber. deutsch. Bot. Gesell. *1:* 31. 1883.
Whetzel, H. H. N. Y. (Cornell) Agr. Exp. Sta. Bul. 239: 1906.

Fusarium sp. Relation to field disease undetermined

Chen, C. C. Maryland Agr. Exp. Sta. Bul. 240: 95. 1920.

Macrosporium sp. Relation to field disease undetermined

Chen, C. C. Maryland Agr. Exp. Sta. Bul. 240: 95. 1920.

Mosaic (Virus)

Pierce, W. H., & C. W. Hungerford. Idaho Agr. Exp. Sta. Bul. 7. 1929.
Reddick, D., & V. B. Stewart. Phytopathology *9:* 443-451. 1919.

Tylenchus dipsaci Kuehn. *Nematode*

Geffart, H. Zeits. f. Pflanzenkr. *40:* 401. 1930.

BECKMANNIA ERUCAEFORMIS (See GRASSES)

BEET *(Beta vulgaris),* including SUGAR BEET

Bacterium aptatum Brown & Jamieson. *Bacterial leaf-spot*

Hirati, Eikiti. Jour. Agr. Exp. Sta. Gov. Gen. Korea *17:* 1-33. 1928. The organism survives not only in sugar-beet seed but also in tops left in the field.

Cercospora beticola Sacc. *Leaf spot*

Nakata, K., T. Nakajima, & K. Takimoto. Tech. Rept. Korea Indus. Model Farm No. 6: 118. 1922.

Coprinus sp. *Seed fungus*

Buller, A. H. R., & Dorothy Newton. Ann. Bot. *41:* 663-670. 1927. Identified as *Coprinus lagopus.* Apparently not parasitic on seedlings.
Pape, H. Mitt. der Biol. Reichs. *17:* 13-16. 1919. Thought to be *Coprinus nycthemerus* Fries. Destroys the seed.

Peronospora schachtii Fckl. Downy mildew

Anon. Calif. Agr. Exp. Sta. Rept. *1930:* 85. 1931. Evidence found that this fungus is carried in and on the seed.

Phoma betae (Oud.) Fr. *Root disease*

Edson, H. A. Jour. Agr. Res. *4:* 135-168. 1915. Found pycnidia and spores on seed. Recognized for years in Europe where seed disinfection is generally practiced.

Stemphylium sp. *Seed fungus*

McWhorter, F. P. Va. Truck Exp. Sta. Bul. 58: 534. 1927. Found on garden-beet seed causing blackening of seed and loss of vitality. Not associated with any field disease of mature plants.

BERMUDA GRASS = CAPRIOLA DACTYLON

BLACK WALNUT *(Juglans nigra)*

Bacterium juglandis (Pierce) EFS. *Bacteriosis*

Smith, R. E., C. O. Smith, and H. J. Ramsey. Calif. Agr. Exp. Sta. Bul. 231: 113-398. 1912. The organism penetrates the kernels, which may become blackened and killed. Also attacks *Juglans californica, J. cinerea, J. hindsii, J. regia,* and *J. sieboldiana.*

BLUEGRASS *(Poa pratense)*

Colletotrichum graminicolum (Ces.) Wils. *Anthracnose*

Selby, A. D., and T. F. Manns. Ohio Agr. Exp. Sta. Bul. 203. 1909.

BRASSICA spp.

(See BROCCOLI, BRUSSELS SPROUTS, CABBAGE, CAULIFLOWER, CHARLOCK, KALE, KOHLRABI, MUSTARD, PAK-CHOI, PE-TSAI, RAPE, SWEDES, TURNIP)

BROAD BEAN *(Vicia faba)*

**Bacillus lathyri* Manns & Taub. *Chocolate spot*

Riker, A. J. Phytopath. *18:* 136. 1928. The disease was studied in England.

Ascochyta pisi Lib.?

Rathschlag, H. Phytopath. Zeitschr. *2:* 493-501. 1930. The fungus enters the cotyledons of the seed through the pod. Seed transmission not proved but very probable.

BROCCOLI *(Brassica oleracea* var. *acephala)*

Mycosphaerella brassicicola (Fr.) Lindau. *Ring spot*

Weimer, J. L. Jour. Agr. Res. *32:* 97-132. 1926. Also attacks cabbage, cauliflower, brussels sprouts, kale, and turnips.

BROME GRASS *(Bromus* spp.)

Bacterium coronafaciens atropurpureum Reddy & Godkin. *Bacterial spot*

Reddy, C. S., & J. Godkin. Phytopath. *13:* 75-86. 1923. Disease probably overwinters in seed. Also attacks quackgrass *(Agropyron repens)* and oats *(Avena).*

Ustilago bromivora (Tul.) Fisch. de Waldh.

A common head smut in many species of Bromus. Undoubtedly seed-borne.

BROOM CORN *(Holcus sorghum)*

Bacterium holci Kend. *Holcus bacterial-spot.* (See SORGHUM)

Brussels Sprouts *(Brassica oleracea gemmifera)*

Bacterium campestre (Pamm.) EFS. *Black rot.* (See CABBAGE)

Mycosphaerella brassicicola (Fries) Lindau. *Ring spot.* (See BROCCOLI)

Phoma lingam (Tode) Desm. *Black leg*

Clayton, E. E. N. Y. (Geneva) Agr. Exp. Sta. Bul. 550. 1927. (See CABBAGE)

Bryanopsis laciniosa

Bacterium lachrymans Smith & Bryan. *Angular leaf spot.* (See CUCUMBER)

Bur Clover *(Medicago hispida)*

Cercospora medicaginis E. & E. *Leaf spot*

Hopkins, E. F. Phytopath. *10:* 66. 1920 (Abstract).

———— Phytopath. *11:* 311-318. 1921. Transmitted almost wholly by seed which bears the hibernating mycelium of the parasite in the seed coat. Suggests seed treatment in formaldehyde (1-240) for two hours.

Pseudoplea medicaginis Miles. *Leaf spot*

Miles, L. E. Phytopath. *15:* 677-690. 1925. The fungus is found in the seeds and has been isolated from them. Final proof that the fungus is seed-transmitted not presented.

Butternut *(Juglans cinerea)*

Bacterium juglandis (Pierce) EFS. *Bacteriosis.* (See BLACK WALNUT)

Cabbage *(Brassica oleracea capitata)*

Alternaria brassicae (Berk.) Sacc. *Black spot*

Chupp, C. C. Manual of Vegetable Garden Diseases 148-149. New York. 1925. May be shown in cabbage seed after treatment with $HgCl_2$, which does not kill the fungus. Hot-water treatment is effective.

Bacterium campestre (Pammel) EFS. *Black rot*

Harding, H. A., F. C. Stewart, and M. J. Prucha. N. Y. (Geneva) Agr. Exp. Sta. Bul. 215: 177-194. 1904.

Walker, J. C., & W. B. Tisdale. Phytopath. *10:* 175-177. 1920.
Hot-water treatment of the seed for 30 minutes at 50° C. is effective in killing organisms in seed but may cause some injury to germination. Chemical disinfection not completely effective. The organism attacks many hosts of the crucifer family.

Fusarium conglutinans Wollenw. *Wilt* or *yellows*

Harter, L. L., & L. R. Jones. U. S. Dept. Agr. Farmers' Bul. 925. 1918.

Manns, Thos. F. Ohio Agr. Exp. Sta. Bul. 238. 1911.
Positive proof of seed dissemination appears to be lacking, though seed disinfection is recommended since the appearance of the disease in certain seedbeds indicates such transmission.

Phoma lingam (Tode) Desm. *Black leg*

Henderson, M. P. Phytopath. *8:* 379-432. 1918. Hot-water treatment of the seed for 25 to 30 minutes at 50° C. is most effective but may cause some injury to the seed. Chemical disinfection not completely effective on cabbage and cauliflower according to Clayton, N. Y. (Geneva) Agr. Exp. Sta. Tech. Bul. 137: 1928. See references under TURNIP. Henderson successfully infected cauliflower; brussels sprouts; kohlrabi; kale; rape; collards; rutabaga; turnip; white, black, Chinese, tumble, hedge, and worm-seed mustard; charlock; cultivated and wild radish; stock; and sweet alyssum. Presumably the disease may be transmitted on the seed of all these plants.

CAPRIOLA *(Cynodon dactylon)* BERMUDA GRASS

**Aplanobacter rathayi* EFS. *Rathay's disease*

Dorph-Peterson, K. Tidsskr. Planteavl. *31:* 87-148. 1925. See also ORCHARD GRASS *(Dactylis)* and RYE *(Secale).*

CARROT *(Daucus carota)*

**Phoma rostrupi* Sacc. = *Ph. sanguinolenta* Rostr.

Rostrup, E. Zeit. f. Pflanzenkr. *4:* 195-196. 1894.

CASTOR BEAN *(Ricinus communis)*

Sclerotinia ricini Godfrey. *Gray mold*

Godfrey, G. H. Jour. Agr. Res. *23:* 679-715. 1923. Immersion for 15 minutes in corrosive sublimate or formaldehyde solution recommended.

CAULIFLOWER *(Brassica oleracea botrytis)*

Alternaria brassicae (Berk.) Sacc. *Leaf spot* and *brown rot*

Weimer, J. L. Jour. Agr. Res. *29:* 421-441. 1924.

Bacterium maculicola McCulloch. *Bacterial spot*

Clayton, E. E. N. Y. (Geneva) Agr. Exp. Sta. Bul. 506: 3-15. 1924.

Bacterium campestre (Pammel) EFS. *Black rot* (See CABBAGE)

Mycosphaerella brassicicola (Fr.) Lindau. *Ring spot* (See BROCCOLI)

Phoma lingam (Tode) Desm. *Black leg*

Clayton, E. E. N. Y. (Geneva) Agr. Exp. Sta. Bul. 550. 1927. (See CABBAGE)

CELERY *(Apium graveolens)*

Phoma apiicola Speg. *Scab, rootrot*

Klebahn, H. Zeitschr. f. Pflanzenkr. *20:* 1-40. 1910.

Septoria apii (Br. & Cav.) Rostr. *Septoria leaf spot, late blight*

Klebahn, H. Jahrb. Hamburg. Wiss. Anst. *30:* B. *3:* 1-57. 1912.

Krout, W. S. Jour. Agr. Res. *21:* 369-372. 1921. Recommends old seed upon which fungus has died.

CHARLOCK *(Brassica arvensis)*

Bacterium campestre (Pamm.) EFS. *Black rot* (See CABBAGE)

CHESTNUT *(Castanea dentata)*

Endothia parasitica (Murr.) And. & And. *Blight*

Collins, J. F. Science *38:* 857-858. 1913.

———— Phytopath. *5:* 233-235. 1915.

Rumbold, Caroline. Phytopath. *5:* 64-65. 1915. Fruits become infected and are thus able to spread the disease.

CHINA ASTER *(Callistephus hortensis)*

Alternaria sp. *Seedling blight*

Gloyer, W. O. N. Y. (Geneva) Agr. Exp. Sta. Tech. Bul. 177. 1931.

May possibly be the conidial stage of *Pleospora herbarum.*

Ascochyta asteris (Bres.) Gloyer. *Leaf spot*
Gloyer, W. O. Phytopath. *14:* 64. 1924.
Botrytis cinerea Pers. *Gray mold*
Gloyer, W. O. Phytopath. *14:* 64. 1924.
Fusarium conglutinans var. *callistephi* Beach. *Wilt*
Beach, W. S. Mich. Acad. Sci. 20. 1918.
Gloyer, W. O. Phytopath. *14:* 64. 1924.
Pleospora herbarum (Pers.) Rab. *Seedling blight*
Gloyer, W. O. N. Y. (Geneva) Agr. Exp. Sta. Tech. Bul. 177. 1931.
Septoria callistephi Gloyer. *Leaf blight*
Gloyer, W. O. Phytopath. *11:* 50-51. 1921.
———— Phytopath. *14:* 64. 1924.

Clover (*Trifolium* spp.)

(See alsike clover, red clover, white clover, etc.)

Cocoanut (*Cocos nucifera*)

**Aphelenchus cocophila* Cobb. *Red-ring nematode*
Field evidence that it was introduced into Grenada and St. Vincent in the husks of seed nuts. Also present in Trinidad, Tobago, South, and Central America.
Stevenson, J. A. Foreign Plant Diseases, U. S. D. A., p. 127. 1926.

Coffee (*Coffea arabica* et al.)

**Cercospora coffeicola* Berk. & Cooke. *Leaf spot*
Nowell, W. Diseases of Crop Plants in Lesser Antilles. London, p. 228. 1923.
**Colletotrichum coffeanum* Noack. *Anthracnose*
Berries become attacked and their market value reduced thereby.
Stevenson, J. A. Foreign Plant Diseases, U. S. D. A., p. 50. 1926.
**Corticium koleroga* (Cooke) von Hach. *"Koleroga" disease*
Berries become infected, as shown by blackened grains.
Stevenson, J. A. Foreign Plant Diseases, U. S. D. A., p. 50. 1926.
**Nematospora coryli* Peglion. *Stigmatomycosis*
Wallace, G. B. Trop. Agr. *7:* 141. 1930. Carried in the beans and probably spread by *Antestia lineaticollis.*

Coffea liberica

**Trachysphaera fructigena* Tabor. & Bunting. *Mealy pod*
Stevenson, J. A. Foreign Plant Diseases, U. S. D. A. p. 51. 1926.

Coix lachrymans (*Job's-tears*)

**Ustilago Coicis* Bref. *Coix smut*
Thomas, C. C. Phytopath. *10:* 331-333. 1920. Occurred on plants grown from seed received from Philippine Islands. Disease not known to be established in U. S.

Corn (*Zea mays*, including sweet corn)

Alternaria sp.
Manns, T. F., & J. F. Adams. Jour. Agr. Res. *23:* 495-524. 1923.
Vallcau, W. D. Ky. Agr. Exp. Sta. Unpublished data: relation to field symptoms unknown. Not controlled by half hour's treatment in $HgCl_2$ 1:1000.

Aspergillus niger VanTiegh. *Black mold*

Taubenhaus, J. J. Texas Agr. Exp. Sta. Bul. 270: 1-38. 1920. Carried in seed and produces death of seedlings.

Bacterium stewartii EFS. *Bacterial wilt*

Smith, E. F. Bacteria in Relation to Plant Diseases *3:* 114-129. 1914.

Stewart, F. C. N. Y. (Geneva) Agr. Exp. Sta. Bul. 130: 437. 1897.
Seed disinfection not effective. Widely distributed by sweet-corn seed. It also attacks flint varieties and to a lesser extent certain dent corns.

Basisporium gallarum Moll. *Dry rot*

Arzberger, E. G. Ohio Agr. Exp. Sta. Bul. 265: 69-82. 1913. Published under name *Coniosporium Gecevi* Bubák.

Durrell, L. W. Iowa Agr. Exp. Sta. Res. Bul. 84: 139-160. 1925.

Botrytis cinerea Pers. *Gray mold*

Pape, H. Mitteil. Biol. Reichs. f. Land. u. Först. *21:* 34-36. 1921. The fungus forms sclerotia on the kernels, which become readily killed.

Cephalosporium acremonium Corda. *Black-bundle disease* (See next entry)

Cephalosporium sacchari Butler. *Wilt* and *root rot*

Manns, T. F., & J. F. Adams. Del. Agr. Exp. Sta. Bul. 138: 3-24. 1921.

Norton, J. B. S., & C. C. Chen. Science *52:* 250-251. 1920. Isolated from sweet corn seed.

Reddy, C. S., & J. R. Holbert. Jour. Agr. Res. *27:* 177-205. 1924.
The relationships of *C. sacchari* and *C. acremonium Corda* are not fully understood. Reddy & Holbert believe that *C. acremonium* is the correct name to apply to this disease, which they designate as the "black bundle disease of corn."

Chaetomium sp. Isolated from internally infected seed grown in several states

Manns, T. F., & J. F. Adams. Jour. Agr. Res. *23:* 495-524. 1923.

Cladosporium sp.

Manns, T. F., & J. F. Adams. Jour. Agr. Res. *23:* 495-524. 1923.

Colletotrichum graminicolum (Ces.) Wils. Isolated from internally infected seed grown in several states: relation of seed infection to field symptoms unknown

Manns, T. F., & J. F. Adams. Jour. Agr. Res. *23:* 495-524. 1923.

Diplodia frumenti E. & E. *Ear rot*

Eddins, A. H. Phytopath. *20:* 733-742. 1920. The organism hibernates as dormant mycelium in the seed and also overwinters in the old cornstalks in the field.

Diplodia macrospora Earle. *Gray ear-mold*

Anon. Fla. Agr. Exp. Sta. Ann. Rept. *1930:* 104. 1931. The fungus overwinters in plant debris in the soil as well as by dormant mycelium in the seed.

Diplodia zeae (Schw.) Lev. *Diplodia ear-rot, seedling blight*

Burrill, T. J., & J. T. Barrett. Ill. Agr. Exp. Sta. Bul. 133: 65-109. 1909.

Melhus, I. E., & L. V. Durrell. Iowa Agr. Exp. Sta. Cir. 78: 2-8. 1922.
Seed disinfection with mercuric dusts is quite effective in reducing loss in stand from this disease.

Fusarium moniliforme Sheldon = *Gibberella moniliforme. Root rot*

Holbert, J. R., W. L. Burlison, B. Koehler, *et al.* Ill. Agr. Exp. Sta. Bul. 255. 1924.

Valleau, W. D. Kentucky Agr. Exp. Sta. Bul. 226. 1920.

Gibberella moniliforme (Sheld.) Wineland

Wineland, G. O. Jour. Agr. Res. *23:* 909-922. 1924. The perfect stage of *Fusarium moniliforme* Sheld.

Gibberella saubinetii (Mont.) Sacc. *Seedling blight, root rot,* and *ear diseases*

Atanasoff, Dimitr. Jour. Agr. Res. *20:* 1-32. 1920. 10-40 percent of infected seeds produced seedling blight. Seed disinfection with mercuric dusts is quite effective in reducing losses.

Pammel, L. M., C. M. King, & J. L. Seal. Iowa Agr. Exp. Sta. Res. Bul. 33: 115-131. 1916.

Selby, A. D., & T. F. Manns. Ohio Agr. Exp. Sta. Bul. 203: 212-236. 1909.

Helminthosporium sp. Relation to field symptoms undetermined

Manns, T. F., & J. F. Adams. Jour. Agr. Res. *23:* 495-524. 1923.

Valleau, W. D. Ky. Agr. Exp. Sta. Unpublished data. Carried internally in a high percentage of seed. Occasionally causing death of seedlings. Not controlled by seed treatment with mercury compounds.

Hormodendron sp. Isolated from internally infected seed grown in North Dakota

Manns, T. F., & J. F. Adams. Jour. Agr. Res. *23:* 495-524. 1923.

Mosaic (Virus)

C. W. Edgerton, La. Agr. Exp. Sta., informed the compiler at Toronto meeting Am. Assoc. Adv. Sci. (1921) that this virus disease is carried in corn seed up to one percent.

Penicillium sp.

Manns, T. F., & J. F. Adams. Jour. Agr. Res. *23:* 495-524. 1923.

Physoderma zeae-maydis Shaw. *Physoderma disease*

Tisdale, W. H. U. S. D. A. Farmers' Bul. 1124: 1-9. 1920. The disease may be carried on the surface of seedcorn to new localities.

Rhizopus nigricans Ehr. *Seedling blight*

Adams, J. F., & A. M. Russell. Phytopath. *10:* 435-453. 1920.

Hoffer, G. N., & J. R. Holbert. Indiana Agr. Exp. Sta. Bul. 224. 1918.

Sclerospora philippinensis Weston. *Philippine downy mildew*

Weston, Wm. H. Jour. Agr. Res. *19:* 97-122. 1920.

———— Jour. Agr. Res. *24:* 853-859. 1923. Serious in the Philippine Islands on several varieties of maize. Recently recognized in U. S. Mycelium from badly infected ears enters undeveloped parts of aborted kernels and occasional hyphae may be found in chaff, seed coats, and endosperm of kernels, but not in embryo; however, attempts to develop the disease from such infected kernels have failed thus far. Weston thinks it more likely that oospores may be seed-borne.

Sphacelotheca reiliana (Kuehn) Clinton. *Head smut* (See SORGHUM)

Spicaria sp.

Manns, T. F., & J. F. Adams. Jour. Agr. Res. *23:* 495-524. 1923.

Torula sp. Isolated from internally infected seed grown in Delaware

Manns, T. F., & J. F. Adams. Jour. Agr. Res. *23:* 495-524. 1923.

COTTON (*Gossypium* spp.)

Alternaria sp. Relation to field disease undetermined

Crawford, R. F. Phytopath. *13:* 501-503. 1923.

Ascochyta gossypii Syd. *Blight*

Wells, B. W., F. A. Wolf, & S. G. Lehman. N. Car. Agr. Exp. Sta. Ann. Rept. *48:* (1925) 34. 1926.

Bacterium malvacearum EFS. *Angular leaf-spot; black arm*

Archibald, R. G. Soil Science *33:* 5-9. 1927.

Faulwetter, R. C. So. Car. Agr. Exp. Sta. Bul. 198. 1919. Concluded that internal transmission of the bacteria was rare and that external transmission was general.

Rolfs, F. M. So. Car. Agr. Exp. Sta. Bul. 184: 14-17. 1915. Thought the bacteria were borne internally.

Worsham, E. Lee. Ga. State Board Ent. Bul. 51: 20-21. 1918. Two-year old seed practically free from infection; one hour treatment with $HgCl_2$ or H_2SO_4 gave control on one-year-old seed.

Cephalothecium sp. Relation to field disease undetermined

Crawford, R. F. Phytopath. *13:* 501-503. 1923.

Diplodia gossypina Cooke. *Black boll-rot*

Crawford, R. F. Phytopath. *13:* 501-503. 1923.

Elliott, J. A. Ark. Agr. Exp. Sta. Bul. 173: 15. 1921.

Fusarium No. 1

Crawford, R. F. Phytopath. *13:* 501-503. 1923.

Fusarium No. 2 Seedling blight

Crawford, R. F. Phytopath. *13:* 501-503. 1923.

Fusarium No. 3 Pink boll-rot

Crawford, R. F. Phytopath. *13:* 501-503. 1923.

Fusarium moniliforme Sheldon. *Dry root-rot*

Woodroff, Naomi C. Phytopath. *17:* 227-238. 1927.

Fusarium vasinfectum Atk. *Wilt*

Elliott, J. A. Phytopath. *12:* 50-51. 1922.

———— Jour. Agr. Res. *23:* 387-393. 1923.

Glomerella gossypii (South.) Edg. *Anthracnose*

Barre, H. W. So. Car. Agr. Exp. Sta. Ann. Rept. *23:* 23-26. 1910.

———— So. Car. Agr. Exp. Sta. Ann. Rept. *24:* 23-45. 1911.

———— So. Car. Agr. Exp. Sta. Bul. 164: 11-15. 1912.

Crawford, R. F. Phytopath. *13:* 501-503. 1923.

Edgerton, C. W. La. Agr. Exp. Sta. Bul. 137: 81-85. 1912.

Elliott, J. A. Phytopath. *12:* 50-51. 1922.

Gilbert, W. W. U. S. D. A. Farmers' Bul. 555: 4-6. 1913.

Worsham, E. Lee. Ga. State Board Ent. Bul. 51: 20. 1918. Cotton seed treated with $HgCl_2$ and H_2SO_4 for one hour gave no control of anthracnose.

Nematospora coryli Pegl. *Boll rot*

Ashby, S. F., & W. Nowell. Ann. Bot. *40:* 69-83. 1926.

Plant Disease Reporter. U. S. D. A. *12:* No. 14. 145-146. 1928.

**Nematospora gossypii* Ashby & Nowell

Ashby, S. F., & W. Nowell. Ann. of Bot. *40:* 69-83. 1926. (Also see *Datura metel)*

**Nematospora nagpuri* D. & S.

Dastur, J. F., & J. Singh. Ann. Myc. *28:* 291-296. 1930. Associated with insect punctures resulting in fibre and embryo infections.

**Spermophthora gossypii* Ashby & Nowell

Ashby, S. F., & W. Nowell. Ann. of Bot. *40:* 69-83. 1926. Found on *Gossypium* spp. in Jamaica and the Lesser Antilles. (Also see COWPEA.)

Cowpea *(Vigna catjang)*

Bacterium pisi (Sack.) EFS. *Bacterial blight* (See PEA)

Bacterium vignae Gard. & Kend. *Bacterial spot*

Gardner, M. W., & J. B. Kendrick. Science *57:* 275. 1922.
——— & ——— Jour. Agr. Res. *31:* 841-863. 1925.
It is believed that the disease may be avoided by using seed from disease-free pods. The pathogen attacks also *Desmodium canescens, Dolichos lablab, Phaseolus angularis, P. limensis, P. limensis* var. *limenanus, P. lunatus macrocarpus, Stizolobium deeringeanum,* and *Vigna sesquipedalis.*

Cladosporium vignae Gard. *Cladosporium spot*

Gardner, M. W. Phytopath. *15:* 453-462. 1925.

Macrosporium sp. Relation to field disease undetermined

Chen, C. C. Md. Agr. Exp. Sta. Bul. 240: 97. 1920.

**Spermophthora gossypii* Ashby & Now.

Ashby, S. F., & W. Nowell. Ann. Bot. *40:* 69-83. 1926. Reported on seeds of cowpea in St. Vincent. Not proved to be seed-transmitted. (Also see COTTON.)

Cranberry *(Vaccinium oxycoccus* and *V. macrocarpum)*

Phoma radiciis oxycocci et al formae Ternetz. *Endotrophic mycorrhiza*

Rayner, M. C. Ann. Bot. *43:* 55-70. 1929. Fungus penetrates deeply into endosperm of seed.
Ternetz, C. Jahrb. Wissen. Bot. *44:* 353-408. 1907.

Cress *(Lepidium sativum)* (GARDEN CRESS)

Phoma lingam (Tode) Desm. *Black leg* (See CABBAGE)

Crimson Clover *(Trifolium incarnatum)*

Bacterium trifoliorum Jones, Will., Wolf, & McCull. *Bacterial leaf-spot* (See ALSIKE CLOVER)

Cucumber *(Cucumis sativus)*

Bacterium lachrymans Smith & Bryan. *Angular leaf-spot*

Carsner, E. Jour. Agr. Res. *15:* 201-220. 1918.
Gilbert, W. W., & M. W. Gardner. Phytopath. *8:* 229-233. 1918.
Meier, F. C., & G. K. K. Link. U. S. D. A. Cir. 234: 1-5. 1922. The pathogen also attacks *Bryanopsis laciniosa, Cucumis anguria, C. dipsaceus, Lagenaria leucantha,* and *Luffa acutangula,* upon which it may also be seed-borne. Seed disinfection with mercuric compounds is quite effective in controlling the disease in seedbeds.

Cercospora melonis Cooke

Eriksson, J. Centralb. f. Bakt. Par. u. Inf. II, *44:* 116-128. 1915. Thought this fungus was seed transmitted by "mycoplasm".

Cladosporium cucumerinum Ellis & Arth. *Scab*

Doolittle, S. P. Mich. Acad. Sci. *17:* (1915): 87-116. 1916. Suggests probability that fungus is disseminated on seed.
Eriksson, J. Centralb. f. Bakt. Par. u. Inf. II, *44:* 116-128. 1915. Thought this fungus was transmitted through seed by "mycoplasm."

Colletotrichum lagenarium (Pass.) Ellis & Hals. *Anthracnose*

Gardner, M. W. U. S. D. A. Bul. 727. 1918.
Garman, H. Ky. Agr. Exp. Sta. Bul. 91. 1901.

Mosaic (Virus)

Bewley, W. F. Nursery & M. G. Ind. Exp. & Res. Sta. Ann. Rept. Cheshunt *11:* 85. 1925.

Doolittle, S. P. U. S. D. A. Bul. 879. 1920. Transmitted through seed in rare cases.

Cucumis anguria; C. dipsaceus

Bacterium lachrymans Smith & Bryan. *Angular leaf-spot* (See cucumber)

Cynodon (See bermuda grass)

Dactylis = orchard grass

Dandelion *(Taraxacum officinale)*

Tylenchus dipsaci Kuehn. *Nematode gall*

Godfrey, G. H. Jour. Agr. Res. *28:* 473-478. 1924.

Darnel *(Lolium temulentum)*

Seed fungus. (Smut?)

Freeman, E. M. Proc. Roy. Soc. (London) *71:* 27-30. 1902.

———— Science *19:* 172. 1904.

———— Minn. Bot. Studies (3d ser.) pt. *3:* 329-334. 1904. Demonstrated the mycelium in the embryo and characterized it as a symbiont.

Guerin, P. Bot. Gaz. *28:* 136-137. 1899. Described the constant presence of fungous mycelium within the seed.

Darso = sorghum

Datura metel

**Nematospora gossypii* Ashby & Nowell

Ashby, S. F., & W. Nowell. Ann. Bot. *40:* 69-83. 1926. On seeds in Montserrat. Also attacks cotton and milkweed.

Desmodium (See tick trefoil)

Dianthus barbatus = sweet william

Dolichos lablab = hyacinth, black, or egyptian bean

(See bacterial diseases under bean, pea, and cowpea)

Durra (See sorghum)

Egg Plant *(Solanum melongena)*

Phomopsis vexans Harter. *Blight*

Edgerton, C. W., & C. C. Moreland. La. Agr. Exp. Sta. Bul. 178. 1921.

Haenseler, C. M. N. J. Agr. Exp. Sta. (Unpublished data). Ninety percent of seeds showing black sclerotial patches and 10 percent of apparently healthy seed yielded pure culture after treatment in $HgCl_2$ 1-1000 for 5 minutes.

Sherbakoff, C. D. Fla. Agr. Exp. Sta. Rept. *1917:* 76R-86R. 1918.

Elymus = wild rye

Puccinia impatientis (Schw.) Arth. *Leaf rust* (See grasses)

ENGLISH WALNUT *(Juglans regia)*

Bacterium juglandis (Pierce) EFS. *Bacteriosis* (See BLACK WALNUT)

EUCHLAENA MEXICANA = TEOSINTE

(See *Sclerospora graminicola* under MILLET)

EVENING PRIMROSE *(Oenothera* spp.)

**Bacillus* (?) *anthracoides* Gal.

Galippe, V. Compt. Rendu. Acad. Sci. Paris. *161:* 112-115. 1915. Constantly present within the seed.

FALSE DANDELION *(Hypochaeris radicata)*

Tylenchus dipsaci Kuehn. *Stem nematode*

Godfrey, G. H. Jour. Agr. Res. *23:* 473-478. 1924.
Hodson, W. E. H. Jour. Helminthol. *7:* 143-152. 1929.

FESCUE *(Festuca* spp.)

Cladochytrium graminis Busgen. (See GRASSES)

FETERITA (See SORGHUM)

Bacterium holci Kend. *Holcus bacterial spot* (See SORGHUM)

FLAX *(Linum* spp.)

Alternaria sp. *Damping-off of seedlings,* or *boll disease*

Bolley, H. L. Proc. Soc. Prom. Agr. Sci. *23:* 82-85. 1902.

**Botrytis cinerea* Auct. *Gray mold*

Schilling, E. Faserfors. *4:* 212-234. 1925.
Schoevers, T. A. C. Rept. Internat. Conf. Phytopath. & Econ. Ent. Holland, 116-117. 1923.

Colletotrichum linicola Peth. & Laff. *Canker*

Bolley, H. L. N. Dak. Agr. Exp. Sta. Bul. *87:* 142-144. 1910.
Pethybridge, G. H., & H. A. Lafferty. Sci. Proc. Royal Dublin Soc. *15:* 359-384. 1918.

Colletotrichum sp. *Seedling blight*

Anon. Dept. Agr. & Tech. Inst. Ireland Ann. Gen. Rept. *18.* 1917-18, p. 60.

Fusarium Lini Bolley. *Wilt*

Bolley, H. L. No. Dak. Agr. Exp. Sta. Bul. *50.* 1901.
———— No. Dak. Agr. Exp. Sta. Bul. *87:* 142-144. 1910.
Tochinai, Y. Jour. Coll. Agr. Hokkaido Imp. Univ. Sapporo, Japan, *14:* 171-236. 1926.

**Gloeosporium lini* West. *Anthracnose*

Westerdijk, Johanna. Jahr. Verein. Angew. Bot. *16:* 1-8. 1918.
This fungus perhaps is the same as *Colletotrichum linicola.*

Melampsora lini (Schum.) Desm. *Rust*

Henry, A. W. Minn. Agr. Exp. Sta. Tech. Bul. *36:* 12-14. 1926.
Pethybridge, G. H. Jour. Dept. Agr. & Tech. Instr. Irel. *22:* 3-20, 1922.
When telia are mixed with the seed and sown the resultant crop may become rusted. Apparently urediniospores do not readily transmit the disease in the same way nor when dusted on the seed.

Phlyctaena linicola Speg. *Pasmo disease*

Brentzel, W. E. Jour. Agr. Res. *32:* 25-37. 1926.

Polyspora lini Laff. *Browning* and *stem break*

Lafferty, H. A. Sci. Proc. Royal Dublin Soc. *16:* 238-274. 1921. The spores retained their viability on dry seed for 2½ years after harvesting.

Foxtail *(Setaria, Chaetochloa)*

Bacterium holci Kend. (See sorghum and millet)

Sclerospora graminicola (Sacc.) Schroet. *Downy mildew*

Melhus, I. E., F. H. Van Haltern, & D. E. Bliss. Iowa Agr. Exp. Sta. Res. Bul. 111. 1928. Proof that this fungus is transmitted naturally on the seed appears to be lacking, but the fact that infection may be produced when the oospores are placed upon the seed at planting time, indicates that this method of transmission is effective and strongly suggests that the disease has become widely established in this manner. There are several other susceptible grass hosts including corn, teosinte, sorghum, and sugar cane.

Gourds *(Cucumis* spp., *Luffa, Lagenaria)*

Bacterium lachrymans Smith & Bryan. *Angular leaf-spot* (See cucumber)

Grasses

See bermuda grass *(Capriola),* darnel *(Lolium), Euchlaena,* brome grass *(Bromus),* fescue, foxtail *(Setaria, Chaetochloa),* job's tears *(Coix),* johnson grass *(Holcus),* oat grass *(Arrhenatherum),* orchard grass *(Dactylis),* millet *(Setaria),* rye grass *(Lolium),* quack, western rye, or wheat grass *(Agropyron)*

Bacterium coronafaciens atropurpureum Reddy & Godkin. *Bacterial spot of bromes*

Reddy, C. S., & James Godkin. Phytopath. *13:* 75-86. 1923. It is suspected that this disease is transmitted by the seed. The pathogen attacks *Agropyron repens, Avena sativa, Bromus inermis,* and 23 other species of Bromus.

**Cladochytrium graminis* Busgen. *Grass blight*

Butler, E. J. Mem. Dept. Agr. India. *1:* 44. 1917. On *Dactylis glomerata* and *Festuca.*

Puccinia beckmanniae McAlpine. *Leaf rust*

McAlpine, D. The Rusts of Australia 43. 1906. On *Beckmannia erucaeformis.* Introduced into Australia on seed from the United States.

Puccinia impatientis (Schw.) Arthur. *Leaf rust*

McAlpine, D. The rusts of Australia 43. 1906. On *Elymus condensatus.*

Sclerospora graminicola (Sacc.) Schroet. *Downy mildew* (See foxtail and millet)

Hawk's Beard *(Crepis taraxacifolia)*

Tylenchus dipsaci Kuehn. *Nematode*

Maige. Bul. Soc. Bot. France (ser. 4 to 6) *53:* Sess. Extra LXXV-LXXVI. 1906. This nema occurs on several hosts in U. S. but not on Crepis so far as known.

Heather *(Calluna vulgaris)*

Phoma radiciis callunae Tern. *Endophytic mycorrhiza*

Rayner, M. C. New Phytol. *12:* 59-77. 1913. Fungus invades seedlings from testa of seed coats.

Ternetz, C. Jahrb. Wissen. Bot. *44:* 353-408. 1907.

Hegari (See sorghum)

Hibiscus

**Bacterium hibisci* Nak. & Tak. *Bacterial blight*

Nakata, N., & K. Takimoto. Ann. Phytopath. Soc. Japan *1:* 13-19. 1923. Can be controlled by seed disinfection with mercuric compounds, or by soaking in water at 55°C. for 10 minutes.

Hippeastrum

Mosaic (Virus)

Dickson, B. T. McDonald College Tech. Bul. 2: 86. 1922.

Newhall, A. G. Phytopath. *13:* 104-106. 1923.

Hordeum (See barley)

Horse Chestnut *(Aesculus hippocastanum)*

Guignardia aesculi (Pk.) Stew. *Leaf blotch*

Detmers, F. Ohio Agr. Exp. Sta. Unpublished data. Lesions in immature fruits noted but their relation to the blotches on leaves not determined, nor whether seed was directly infected. In 1902 seeds collected under a seriously infected tree were planted in the greenhouse. Leaves of the resulting seedlings were seriously blotched.

Hyacinth Bean *(Dolichos lablab)*

(See bacterial diseases under bean, cowpea, and pea)

Hypochaeris radicata = false dandelion

Job's-tears = coix lachrymans

Johnson Grass *(Holcus halapensis)*

(See *Bacterium holci* under sorghum)

Juglans *(Walnut)*

Bacterium juglandis (Pierce) EFS. *Bacteriosis* (See black walnut)

Kale *(Brassica oleracea acephala)*

Bacterium campestre (Pammel) EFS. *Black rot* (See cabbage for this and other diseases)

Mycosphaerella brassicicola (Fr.) Lindau. *Ring spot* (See broccoli)

Phoma lingam (Tode) Desm. (See cabbage)

Kafir (See sorghum)

KOHLRABI *(Brassica oleracea caulo-rapa)*

Bacterium campestre (Pammel) EFS. *Black rot* (See CABBAGE for this and other diseases)

Phoma lingam (Tode) Desm. *Black leg* (See CABBAGE)

KAOLIANG (See SORGHUM)

KUDZU *(Pueraria thunbergiana)*

Bacterium puerariae Hedges. *Halo blight*

Hedges, Florence. Phytopath. *20:* 140. 1930. This disease is said by Miss Hedges to be the same as that of beans caused by *Bact. medicaginis phaseolicola* Burk. The organism attacks also *Phaseolus lunatus macrocarpus.*

LAGENARIA LEUCANTHA

Bacterium lachrymans Smith & Bryan. *Angular leaf-spot* (See CUCUMBER)

LATHYRUS LATIFOLIUS = EVERLASTING PEA

Bacterium pisi (Sack.) EFS. *Bacterial blight* (See PEA)

LATHYRUS ODORATUS = SWEET PEA

LETTUCE *(Lactuca sativa)*

Alternaria sp. Relation to field symptoms undetermined

Valleau, W. D. Ky. Agr. Exp. Sta. Unpublished. Found generally in certain lots of seed. Determined both by culture and by sectioning seed.

Marssonina panattoniana (Berl.) Magn. *Anthracnose*

Proof of seed transmission not published up to 1918. Claimed to be seed-borne in England. Also stated by Brittlebank to be introduced into Australia on seed.

Mosaic (Virus)

Newhall, A. G. Phytopath. *13:* 104-106. 1923.

Septoria sp. *Leaf spot*

Smith, E. F. Trans. Mass. Hort. *1897:* 129. 1898. "Appears to be carried over from year to year and spread from place to place in the seed." Probably *S. consimilis* E. & M., which is rather widely distributed.

LIMA BEAN *(Phaseolus lunatus macrocarpus)*

Bacterium flaccumfaciens Hedges. *Bacterial wilt* (See BEAN)

Bacterium medicaginis var. *phaseolicola* (Burk.) L. & H. *Halo blight* (See BEANS)

Bacterium phaseoli EFS. *Bacterial blight* (See BEANS)

Bacterium phaseoli var. *sojense* Hedges. *Bacterial pustule* (See SOYBEANS)

Bacterium puerariae Hedges = *B. medicaginis* var. *phaseolicola*

Bacterium vignae Gard. & Kend. *Bacterial spot of cowpea* (See COWPEA)

Bacterium viridifaciens T. & W. *Bacterial spot.* = *B. vignae* Gard. & Kend.

Tisdale, W. B., & Maud M. Williamson. Jour. Agr. Res. *25:* 141-153. 1923.

Diaporthe phaseolorum (C. & E.) Sacc. *Pod blight*

Halsted, B. D. N. J. Agr. Exp. Sta. Bul. 151: 24-25. 1901. Described as *Phyllosticta subcircinata* E. & E., but not demonstrated by Halsted as seed-borne.

Harter, L. L. Jour. Agr. Res. *11:* 473-506. 1917.

Elsinoe canavaliae Rac. *Scab*

Jenkins, A. E. Jour. Agr. Res. *42:* 13-23. 1931. Fruits are commonly infected. The organism is very likely seed-borne but proof is lacking.

Fusarium sp. Relation to field disease unknown

Chen, C. C. Md. Agr. Exp. Sta. Bul. 140: 97-98. 1920. Fungus emerges through hilum. Possibly this may be a wilt fungus.

Mosaic (Virus)

McClintock, J. A. Phytopath. *7:* 60-61. 1917.

Nematospora phaseoli Wingard. *Seed spot*

Wingard, S. A. Phytopath. *12:* 525-532. 1922.

Phytophthora phaseoli Thaxter. *Downy mildew*

Butler, E. J. Fungi and Disease in Plants, 234-235. 1918.
Clinton, G. P. Ill. Agr. Exp. Sta. Bul. 57. 1900.

Luffa acutangula

Bacterium lachrymans Smith & Bryan. *Angular leaf-spot* (See cucumber)

Lupine (*Lupinus* sp.)

Bacterium leguminiperdum (von Oven) *Stevens* (See beans)

Mangel (See sugar beet)

Martynia louisiana

Bacterium martyniae Elliott. *Bacterial leaf-spot*

Elliott, C. Jour. Agr. Res. *29:* 487-490. 1924. Author recommends using seed only from healthy plants of the host.

Meibomia (See tick trefoil)

Melandryum album

**Ustilago violacea* (Pers.) Tul. *Anther smut*

Brefeld, O., & R. Falck. Untersuch. Gesammt. Myk. *13:* 1-75. 1905.

Milkweed (*Asclepias curassavica*)

**Nematospora gossypii* Ashby & Nowell

Ashby, S. F., & W. Nowell. Ann. Bot. *40:* 69-83. 1926. In seeds of *A. curassavica* in Trinidad and W. Indies.

Millet *(Chaetochloa, Panicum, Pennisetum, Setaria)*

Bacterium panici Elliott. *Stripe disease.* See also African millet *(Eleusine)*

Elliott, C. Jour. Agr. Res. *26:* 151-159. 1923. The disease attacks panicles of *Panicum miliaceum,* where every opportunity for seed infection is afforded.

Phoma sp.

Porter, R. H., T. F. Yu, & H. K. Chen. Phytopath. *18:* 917-918. 1928. Commonly found on millet *(Setaria italica)* seed in China.

Sclerospora graminicola (Sacc.) Schroet. *Downy mildew*

Melhus, I. E., F. H. Van Haltern, & D. E. Bliss. Iowa Agr. Exp. Sta. Bul. 111: 297-338. 1928. There is every evidence that intercontinental spread has been accomplished by oospores in or on the seed. Reported on *Euchlaena mexicana, Holcus sorghum, Panicum miliaceum, Pennisetum typhoideum, Saccharum officinarum, Setaria glauca, S. italica, S. magna, S. verticillata, S. viridis* and varieties of *Zea mays,* including pop, sweet, and field corns.

Weston, W. H. Jour. Agr. Res. *24:* 854. 1923.

Ustilago crameri Koern. *Head smut*

Butler, E. J. Fungi and Disease in Plants, 234-235. 1918.

Clinton, G. P. Ill. Agr. Exp. Sta. Bul. 57: 1900.

Porter, R. H., T. F. Yu, & H. K. Chen. Phytopath. *18:* 911-919. 1928. Seed disinfection with mercury, copper, and arsenic dusts is quite effective. On *Chaetochloa (Setaria) italica.*

Ustilago panici-miliacei (Pers.) Wint. *Head smut*

Butler, E. J. Fungi and Disease in Plants, 235-238. 1918. On *Panicum miliaceum* and other species allied.

Milo (See sorghum)

Mulberry *(Morus* spp.)

**Microglossum shiraianum* P. Henn.

Siegler, E. A., & A. E. Jenkins. Jour. Agr. Res. *23:* 833-836. 1923. Forms sclerotia in fruits.

Sclerotinia carunculoides Sieg. & Jenk. *Popcorn disease*

Siegler, E. A., & A. E. Jenkins. Jour. Agr. Res. *23:* 833-836. 1923. Fungus infects individual druplets, causing complete infection of ovaries and transformation of druplets into swollen sclerotial bodies which later produce apothecia.

**Sclerotinia shiraiana* P. Henn. *Sclerotium disease*

Siegler, E. A., & A. E. Jenkins. Jour. Agr. Res. *23:* 833-836. 1923. Causes formation of sclerotium, involving entire aggregate fruit.

Muskmelon *(Cucumis melo)*

Colletotrichum lagenarium (Pass.) Ellis & Hals. *Anthracnose* (See cucumber)

Cardinell, H. H., & E. M. Page. Mo. Agr. Exp. Sta. Service Circ. *110:* 13. 1922.
Link, G. K. K., & F. C. Meier. U. S. D. A. Circ. 217: 1-4. 1922.

Mustard *(Brassica alba, B. campestris, B. juncea, B. nigra)*

Bacterium campestre (Pammel) EFS. *Black rot* (See cabbage)

Phoma lingam (Tode) Desm. *Black leg* (See cabbage)

OATS *(Avena sativa)*

Bacterium coronafaciens Elliott. *Halo blight*

Elliott, Charlotte. Jour. Agr. Res. *19:* 139-172. 1920.

Bacterium coronafaciens atropurpureum Reddy & Godkin. *Bacterial spot*

Reddy, C. S., & J. Godkin. Phytopath. *13:* 75-86. 1923.

Bacterium striafaciens Elliott. *Bacterial stripe blight*

Elliott, Charlotte. Jour. Agr. Res. *35:* 811-824. 1927. Since the disease attacks pedicels, glumes, and the entire panicle, there is every opportunity for seed infection.

Cephalobus elongatus Sch. *Nematode disease*

Hodson, W. E. H. Nature *116:* 135. 1925. Nemas of this species are disseminated by oat seeds and in this manner transmitted to the resultant seedlings.

Colletotrichum graminicolum (Ces.) Wils. *Anthracnose* (See BARLEY, RYE, and WHEAT)

**Fusarium avenaceum* (Fries) Sacc.

Tu, C. Phytopath. *19:* 143-154. 1929. Inoculation caused headblight in oats. Ample opportunity is thus afforded for seed transmission though experimental proof seems to be lacking.

Fusarium culmorum (W. G. Sm.) Sacc.

Tu, C. Phytopath. *19:* 143-154. 1929. (See note under *F. avenaceum.)*

Fusarium graminearum Schwabe = *Gibberella saubinetii*

Fusarium nivale Sor. = *Calonectria graminicola* (B. & Br.) Wr. *Snow mold*

Tu, C. Phytopath. *19:* 143-154. 1929.
This disease is well known in Europe, where it is undoubtedly seed-borne. Reported by H. W. Wollenweber, Phytopath. *3:* 34. 1913, as widely distributed in North America.

Fusarium solani (Mart. p. par.) Ap. & Wr.

Tu, C. Phytopath. *19:* 143-154. 1929. See note under *F. avenaceum.*

Gibberella saubinetii (Mont.) Sacc. *Scab*

Atanasoff, D. Jour. Agr. Res. *20:* 1-32. 1920.
Dickson, J. G. U. S. D. A. Farmers' Bul. 1599. 1929.

Helminthosporium avenae Eidam. *Leaf spot*

Atanasoff, D., & A. G. Johnson. Jour. Agr. Res. *18:* 379-390. 1920.
Rathschlag, H. Phytopath. Zeitschr. *2:* 469-492. 1930. Establishes the perfect stage as *Pleospora avenae* Schaff. & Rath.
Ravn, F. K. Bot. Tidsskr. *23:* 101-321. 1900.
Sawada, K. Formosa Agr. Exp. Sta. Spec. Bul. *19:* 638. 1919.

Ustilago avenae (Pers.) Jens. *Loose smut*

Kuehn, J. Krankheiten der Kulturgewächse, 1858.
Wolff, R. Der Brand des Getreides, Halle. p. 1-34. 1873.
Zade, A. Angew. Bot. *6:* 113-125. 1924.

Ustilago levis (Kell. & Sw.) Magn. *Covered smut*

Clinton, G. P. Ill. Agr. Exp. Sta. Bul. 57. 1900.
Kellerman, W. A., & W. T. Swingle. Kansas Agr. Exp. Sta. Rept. *2:* 213. 1890.

OAT GRASS *(Arrhenatherum elatius = Avena elatior)*

Ustilago perennans Rostr. *Smut*

Rostrup, E. Overs. K. Danske Vidensk. Selsk. Forh. *1890:* 1-16. 1890.

OKRA *(Hibiscus esculentus)*

Ascochyta abelmoschi Harter. *Pod spot*

Harter, L. L. Jour. Agr. Res. *14:* 207-212. 1918.

ONION *(Allium cepa)*

Botrytis allii Munn. *Neck rot*

Munn, M. T. N. Y. (Geneva) Agr. Exp. Sta. Bul. 437. 1917. Spores found on centrifuged seed.

Macrosporium porri Ellis. *Brown mold*

Chapman, G. H. Mass. Agr. Exp. Sta. Rept. *22:* 164-167. 1910.

Peronospora schleideni Unger. *Downy mildew*

Chapman, G. H. Mass. Agr. Exp. Sta. Rept. *22:* 164-167. 1910. Spores commonly present in commercial samples of onion seed.

Cooke, H. T. Phytopath. *20:* 139-140. 1930. Demonstrated mycelium in ovary and ovules.

Whetzel, H. H. N. Y. (Cornell) Agr. Exp. Sta. Bul. 218. 1904. Spores are found in sets and may thus disseminate the disease.

Urocystis cepulae Frost. *Smut*

Chapman, G. H. Mass. Agr. Exp. Sta. Rept. *22:* 164-167. 1910.

Kokubu, K. Jour. Plant Protect. *8:* 245-250. 1921.

Munn, M. T. N. Y. (Geneva) Agr. Exp. Sta. Bul. 437. 1917.

ORCHARD GRASS *(Dactylis glomerata)*

**Aplanobacter rathayi* EFS. *Rathay's disease*

Smith, E. F. Carnegie Inst. Wash. *3:* No. 27, 155-160. 1914.

Cladochytrium graminis Busgen (See GRASSES)

Colletotrichum graminicolum (Ces.) Wils. (See WHEAT)

ORCHIDS

(Cattleya, Cypripedium, Epipactis, Neottia, Odontoglossum, etc.)

Rhizoctonia spp. *Endotrophic mycorrhizas*

Bernard, N. Compt. Rend. Acad. Sci. Paris *138:* 828-830. 1904.

———— Ann. Sci. Nat. Bot. Ser. *9:* 1-196. 1909.

Burgeff, H. Die Wurzelpilze der Orchideen. Fischer, Jena. 1909. Described these fungi as species of *Orcheomyces.*

PAK-CHOI *(Brassica chinensis)*

Bacterium campestre (Pamm.) EFS. *Black rot* (See CABBAGE)

PANSY *(Viola* spp.) (See VIOLET)

PEA *(Pisum sativum)*

Ascochyta pinodella Jones. *Ascochyta foot-rot*

Jones, L. K. N. Y. (Geneva) Agr. Exp. Sta. Bul. 547: 1-46. 1927. This fungus has smaller conidia than either *A. pisi* or *A. pinodes.* It is of importance in the seed producing regions as a foot rot and also a blight of seedlings.

Ascochyta pisi Lib. *Leaf* and *pod-spot*

Halsted, B. D. N. J. Agr. Exp. Sta. Rept. *1893:* 357-362. 1894.

Krueger, F. Central. Bakt. u. Parasit. *1:* 620-624. 1895.

Van Hook, J. M. Ohio Agr. Exp. Sta. Bul. 173: 231-239. 1906. Observed by Halsted and Krueger on seed but proved to cause infection of plants from such source by Van Hook.

Bacillus lathyri Manns & Taub. *Streak* (See ALFALFA)

Bacterium leguminiperdum (von Oven) Stevens (See BEANS)

Bacterium pisi (Sack.) EFS. *Bacterial blight*

Jennison, H. M. Phytopath. *11:* 104. 1921.
Jones, F. R., & M. B. Linford. Wis. Agr. Exp. Sta. Res. Bul. 64: 25-26. 1925.
Sackett, W. G. Colo. Agr. Exp. Sta. Bul. 218: 1-43. 1916.
Skoric, Vladimir. Phytopath. *17:* 611-627. 1927. The bacteria overwinter on and in the seed and transmit the disease to the resultant seedlings. The pathogen also attacks *Lathyrus odoratus. L. latifolius, Vigna* sp., and *Dolichos lablab.*

Bacterium seminum (Cayley) Stevenson. *Marsh spot*

Cayley, Dorothy. Proc. Royal Soc. (London) Ser. B. *86:* 171-173. 1913.
Paine, S. G. Ann. Appl. Biol. *5:* 62-67. 1918.

Erysiphe polygoni DC. *Powdery mildew*

Crawford, R. F. New Mexico Agr. Exp. Sta. Bul. 163: 1-13. 1927. The only case known of a powdery mildew which has been proved to be seed-borne.

Macrosporium sp. Relation of disease to field infection not determined

Munn, M. T. Unpublished. On garden peas; also on Canada field peas.

Mosaic (Virus)

Blaringhem, L. Compt. Rend. Acad. Sci. Paris. *175:* 1432-1434. 1922.
Dickson, B. T. McDonald College Tech. Bul. 2: 86. 1922.

Mycosphaerella pinodes (Berk. & Blox.) Stone. *Mycosphaerella blight*

Jones. L. K. N. Y. (Geneva) Agr. Exp. Sta. Bul. 547: 1-46. 1927. This disease was confused in the earlier literature with *A. pisi,* with which it has no genetic connection according to present workers. The conidial stage is *Ascochyta pinodes* (Berk. & Blox.) Jones.

Septoria pisi West. *Leaf blotch*

Jones, F. R., & M. B. Linford. Wis. Agr. Exp. Sta. Res. Bul. 64: 24. 1925. "Seed infection is not infrequent."

PEANUT *(Arachis hypogaea)*

Cercospora personata (B. & C.) Ellis. *Blotch* or *tikka disease*

Butler, E. J. Fungi and Disease in Plants. 319-323. 1918.
Wolf, F. A. Ala. Agr. Sta. Bul. 180: 127-139. 1914.

Sclerotinia minor Jagger (?) *Root rot*

Valleau, W. D. Ky. Agr. Exp. Sta. Unpublished. Sclerotia found inside shells. Determined as probably *S. minor* by H. H. Whetzel. Roots badly diseased.

Sclerotium rolfsii Sacc. *Sclerotial rot*

Wolf, F. A. Ala. Agr. Exp. Sta. Bul. 180: 142-147. 1914. Also widely disseminated in the soil and upon all sorts of vegetation.

PEPPER *(Capsicum annuum)*

Bacterium vesicatorium Doidge. *Bacterial canker* (See TOMATO)

Higgins, B. B. Phytopath. *12:* 501-516. 1922.

Cercospora capsici Heald & Wolf. *Leaf spot*

Higgins, B. B. Phytopath. *13:* 57-58. 1923.
———— Ga. Agr. Exp. Sta. Bul. 141: 57-59. 1923.

Colletotrichum sp. *Fruit spot*

Higgins, B. B. Phytopath. *13:* 57-58. 1923.

Gloeosporium piperatum E. & E. *Anthracnose*

Higgins, B. B. Phytopath. *13:* 57-58. 1923.
———— Ga. Agr. Exp. Sta. Bul. 141: 48-75. 1923.
———— Phytopath. *16:* 333-345. 1926. Surface disinfection of seed reduces disease greatly.

Macrosporium solani E. & M. *Early blight*

Higgins, B. B. Phytopath. *13:* 57-58. 1923.
———— Ga. Agr. Exp. Sta. Bul. 141: 66-67. 1923.

Phoma destructiva Plowr. *Phoma fruit-rot*

Higgins, B. B. Phytopath. *13:* 57-58. 1923.
———— Ga. Agr. Exp. Sta. Bul. 141: 67-69. 1923. (See TOMATO also.)

Phytophthora capsici Leonian. *Stem* and *fruit-blight*

Leonian, L. H. Phytopath. *12:* 401-408. 1922. Demonstrated seed transmission by planting infected seed. Recommends seed selection.

Vermicularia capsici Syd. *Fruit rot*

Higgins, B. B. Ga. Agr. Exp. Sta. Bul. 162: 1-10. 1930.

PERNETTYA MUCRONATA

Endotrophic mycorrhiza

Raymer, M. C. Tran. Bul. Mycol. Soc. *8:* 62. 1922. Seedling infection from seed coats was observed in seeds germinating viviparously.

PE-TSAI *(Brassica pe-tsai)*

Bacterium campestre (Pamm.) EFS. *Black rot* (See CABBAGE)

PETUNIA *(Petunia hybrida)*

Ring spot (Virus) (See TOBACCO)

Henderson, R. G. Phytopath. *21:* 225-229. 1931. Tobacco "ring spot" is seed-borne on this host to the extent of about 20 percent.

PIGEON PEA *(Cajanus indicus)*

Colletotrichum cajani Rangel. *Anthracnose*

Tucker, C. M. Jour. Agr. Res. *34:* 589-596. 1927.

PISUM SATIVUM = PEA

PLANTAIN *(Plantago maritima, P. major)*

Tylenchus dipsaci Kuehn. *Stem nematode*

Hodson, W. E. H. Jour. Helminthol. *7:* 143-152. 1929.

POMEGRANATE *(Punica granatum)*

Nematospora coryli Pegl. *Inspissosis*

Fawcett, H. S. Phytopath. *19:* 479-482. 1929. Seed infection reported. Transmission not proved but probable.

POPPY *(Papaver* spp.)

Bacterium papavericola Bryan & McWh.

Bryan, M. K., & F. P. McWhorter. Jour. Agr. Res. *40:* 1-9. 1930. Pods become infected and ample opportunity for seed infection is afforded.

Pumpkin *(Cucurbita pepo)*

Undetermined fungus. Relation to field infection not demonstrated.
Munn, M. T. Proc. Assoc. Off. Seed Analysts *12-13:* 57-59. 1921. Germination affected seriously.

Quackgrass *(Agropyron repens)*

Bacterium coronafaciens atropurpureum Reddy & Godkin. (See brome grass)

Radish *(Raphanus sativus)*

Bacterium campestre (Pamm.) EFS. *Black rot* (See cabbage)

Bacterium vesicatorium raphani White. *Bacterial spot*

White, H. E., & M. W. Gardner. Phytopath. *19:* 97. 1929.
White, H. E. Phytopath. *20:* 653-662. 1930. This disease also attacks turnips, cabbage, brussels sprouts, cauliflower, mustard, and tomato, but seed transmission has been proved only in the case of radish.

Phoma lingam (Tode) Desm. *Black leg* (See cabbage)

Rape *(Brassica napus)*

Bacterium campestre (Pamm.) EFS. *Black rot* (See cabbage)

Phoma lingam (Tode) Desm. *Black leg* (See cabbage)

Red Clover *(Trifolium pratense)*

Alternaria sp. *Seed fungus*

Fergus, E. N., & W. D. Valleau. Ky. Agr. Exp. Sta. Bul. 269: 197-199. 1926. Frequently isolated from seeds disinfected in formaldehyde.
Munn, M. T. N. Y. (Geneva) Agr. Exp. Sta. (unpublished) on Italian red clover. Possibly same organism as that found by Fergus and Valleau.

Bacillus lathyri Manns & Taub. *Streak* (See alfalfa)

Bacterium trifoliorum Jones, Will., Wolf, & McCull. *Bacterial leaf spot* (See alsike clover)

**Botrytis anthophila* A. Bond. *Blossom mold*

Bondarstev, A. S. Zap. Sta. Isp. Siem. Imp. Bot. Sad. *2:* No. 3: 3-23. 1914.
Jaczewski, A. A. Min. Zem. Biûro. Mik. Fitopat. Uchen. Kom. 31-37. 1916.

Colletotrichum trifolii Bain. *Anthracnose* (See alfalfa)

Sampson, Kathleen. Comparative Studies of *Kabatiella caulivora* (Koch.) Karuk. and *Colletotrichum trifolii* Bain and Essary, Two Fungi which Cause Red Clover Anthracnose. Trans. Brit. Myc. Soc. *13:* 103-142. 1928. Found *C. trifolii* transmitted to seedlings when seed was contaminated with spores.

Gloeosporium caulivorum Kirch. *Anthracnose*

Drayton, F. L. Dom. Canada Plant Dis. Sur. p. 32. 1923. The disease was destructive in seed plots planted with seed obtained in Europe. Species of clover not stated. Proof of seed-borne character not yet proved.
Sampson, Kathleen. Comparative studies of *Kabatiella caulivora* (Koch.) Karuk. and *Colletotrichum trifolii* Bain and Essary, Two Fungi which Cause Red Clover Anthracnose. Trans. Brit. Myc. Soc. *13:* 103-142. 1928. Spores (conidia) lived on red clover seed for 18 months under laboratory conditions. Infested seed produced the disease.

Kabatiella caulivora = *Gloeosporium caulivorum*

Macrosporium sarcinaeforme Cav. *Large leaf-spot*

Krakover, L. J. Mich. Acad. Sci. Rept. *19:* 275-328. 1917. Proof of seed dissemination not yet fully established, but *prima facie* evidence points strongly in this direction.

Mosaic (Virus)

Dickson, B. T. McDonald College Tech. Bul. 2: 82-86. 1922.

Mycelia sterilia. Seed fungus

Fergus, E. N., & W. D. Valleau. Ky. Agr. Exp. Sta. Bul. 269: 197-199. 1926. Found occasionally on formaldehyde disinfected seed. Hyphae rust-colored.

Peronospora trifoliorum deBary. *Downy mildew*

Campbell, Carlo. Ann. di Bot. *15:* 283-284. 1922.
Reported in U. S. on *T. repens.* U. S. Dept. Agr. Dept. Bul. 1366. 1926.

Sclerotinia trifoliorum Eriks. *Root rot*

Wolf, F. A., & R. O. Cromwell. N. C. Agr. Exp. Sta. Tech. Bul. 16: 15-18. 1919. Sclerotia found with the seed.

Sphaerulina trifolii Rostr. *Sphaerulina leaf-spot*

Hopkins, E. F. Phytopath. *13:* 117-126. 1923. Infection of seed may occur. Occurs on white clover as well.

Tylenchus dipsaci Kuehn. *Nematode* or *eelworm disease*

Smith, Ralph H. Idaho Agr. Exp. Sta. Bul. 130: 1922. Carried chiefly on plant debris "with" the seed. Thorough cleaning is of considerable benefit in preventing its spread. Dr. Cobb found this nematode in seed harvested in Idaho.

Rice *(Oryza sativa)*

Alternaria sp. *Leaf spot*

Tisdale, W. H. U. S. Dept. Agr. Bul. 1116: 4-5. 1922. Isolated from seed and found associated with a leaf-spot of rice in the field from which Alternaria was readily isolated.

Aspergillus, Epicoccum, Fusarium, and *Penicillium.* Seed-borne organisms whose relation to disease in field has not been established.

Tisdale, W. H. U. S. Dept. Agr. Bul. 1116: 4. 1922. Thinks these organisms enter kernels before they are mature; the spores probably lodging between glumes at flowering time.

**Fusarium heterosporium* Nees. *"Bakanae" disease*

Sawada, K. Formosa Agr. Exp. Sta. Spec. Bul. 19: 251. 1919.
———— Formosa Agr. Exp. Sta. Agr. Bul. 21.
The perfect stage is claimed to be *Lisea fujikuroi* Sawada.

Gibberella saubinetii (Mont.) Sacc. *Seedling blight, head blight,* and *stem rot*

Kasai, M. Ber. Ohara Inst. Landw. Forsch. *2:* 259-272. 1923.

Helminthosporium oryzae Miy. & Hori. *Brown spot, "sesame"*

Nishikado, Y., & C. Miyake. Jour. Plant Protect. *5:* 693-712. 1918. About 50 percent of the disease arises from infected seed. Soak the seed 24 hours in water at room temperature and follow with water at 52° C. for 10 minutes, or 54° C. for 5 minutes.

Tisdale, W. H. U. S. Dept. Agr. Bul. 1116: 4. 1922. Isolated Helminthosporium from seed and considered it to be parasitic. Its identity with *H. oryzae* is probable.

Lisea fujikuroi Sawada = *Fus. heterosporium*

Piricularia grisea (Cooke) Sacc. *Blast*

Tisdale, W. H. U. S. Dept. Agr. Bul. 1116: 4. 1922. Isolated from seed though not usually considered to be a seed-borne parasite. Nishikado & Miyake failed to control Piricularia by the hot-water treatment and regarded this as additional evidence that the fungus was not seed-borne.

**Protoascus colorans* Wolk. *Yellow grain*

Wolk, P. C. van der. Mycol. Centralbl. *3:* 153-157. 1913.

Sclerotium oryzae Catt.

Stevenson, J. A. Foreign Plant Diseases, U. S. Dept. Agr., p. 126. 1926. The sclerotia which are small, black, and spherical are carried with the seed and were introduced from the Orient to the U. S. A. in this manner.

Sclerotium sp. *Seedling blight*

Godfrey, G. H. Phytopath. *10:* 342-343. 1920.
Tisdale, W. H. U. S. Dept. Agr. Bul. 1116: 1-11. 1922.

Tilletia horrida Tak. *Covered smut*

Butler, E. J. Fungi and Disease in Plants. 226. 1918. The method of infection is not known with certainty.
Fulton, H. R. La. Agr. Exp. Sta. Bul. 105: 24-28. 1908.
Takahashi, Y. Bot. Mag. Tokio *11:* 16-20. 1896.

Rose *(Rosa* spp.)

Botrytis cinerea. Bud rot

Whetzel, H. H. In correspondence of Feb. 2, 1929, Dr. Whetzel states that sclerotia of a Botrytis causing bud-rot of certain varieties of rose sometimes are found attached to the seeds. The disease may be distributed in this manner.

Rye *(Secale cereale)*

**Aplanobacter rathayi* EFS. *Rathay's disease*

Flachs. Illust. Landw. Zeit. Berlin *47:* 262. 1927. Assumed to be seed-borne on rye because of our knowledge concerning this feature on *Capriola* and *Dactylis.*

Bacterium translucens var. *undulosum* Smith, Jones, & Reddy. *Bacterial blight* (See WHEAT)

**Bacterium cerealinum* (Gentner) Elliott. *Bacteriosis of Gentner* (See BARLEY)

Cladosporium herbarum (Pers.) Link. *Black end; sooty mold*

Corda. Oekonom. Neuigk. Verhandl. *72:* 651. 1846. Corda recognized the destructive action of this fungus on rye plants and especially the seed grains, which become shriveled and worthless.
Haberlandt, G. Wiener Land. Zeit. 245. 1878. Believed that the disease was transmitted on seed and also by straw in the manure.
Lapriore, G. Land. Jahrb. *23:* 969, 1008. 1894. Proved that seed transmitted the disease. Perfect stage claimed to be *Mycosphaerella tulasnei* Janc.

Claviceps purpurea (Fries) Tul. *Ergot*

"Sclerotia" are carried with the seed.

Colletotrichum graminicolum (Ces.) Wils. *Anthracnose* (See WHEAT)

Dilophospora alopecuri Fries. *Dilophospora disease*

Atanasoff, D. Phytopath. *15:* 11-40. 1925. The infected seed invariably carries the nematode *Tylenchus tritici* (Stein.) Bast. Also such seed galls are quite generally distributed with the seed. The galls may be separated from seed by the salt-solution method. Also attacks wheat and spelt.

**Fusarium avenaceum* (Fr.) Sacc. = *F. subulatum*

Fusarium culmorum (W. G. Smith) Sacc. *Scab* and *seedling blight*

Appel, O., & Fuchs. Mitt. Kaiserl. Biol. Anst. *14:* 10. 1913.

Fusarium graminearum Schwabe = *Gibberella saubinetii*

Fusarium herbarum (Corda) Fries. *Head* and *seedling blight*

Atanasoff, D. Meded. Land. (Wageningen) *27:* No. 4, p. 56, 73-75. 1923. Known in Holland and U. S. A.

Fusarium metachroum App. & Wollenw. = *F. herbarum* (Corda) Fries, according to Atanasoff

Fusarium nivale (Fries) Ces. = *Calonectria graminicola* (B. & Br.) Wr. *Snow mold* and *root disease*

Hiltner, L., and G. Ihssen. Landw. Jahrb. Bayern *1:* 20-60, 315-362. 1911. Records experiments in seed treatment with 1% $HgCl_2$, which produced better germination, more vigorous growth, and larger yields than was obtained from untreated seed.

Schaffnit, E. Landw. Jahrb. *43:* 521-648. 1913.

**Fusarium subulatum* App. & Wollenw. *Seedling* and *head blight*

Naumov, N. A. Min. Zeml. (Russia) Trudy Biûro Mykol. i. Fitopat. Uchen. Kom. No. *12:* 1-216. 1916.

Now known to be rather widely distributed in Europe. Often listed as *F. avenaceum.*

Gibberella saubinetii (Mont.) Sacc. *Scab* (See WHEAT)

Helminthosporium sp. *Helminthosporium blight*

Stakman, L. J. Minn. Agr. Exp. Sta. Bul. 191: 4-18. 1920.

Helminthosporium sativum P. K. & B. *Spot blotch* (See BARLEY)

Rhynchosporium secalis (Oud.) Davis

Heinsen, E. Jahr. Hamb. Wiss. Anst. *3:* No. 18: 43-55. 1901.

**Sclerotinia temulenta* (Pr. & Del.) Sacc. & D. Sacc. *Sclerotium disease of rye* in France

Prillieux, E. Mal. Pl. Agr. *2:* 453-459. 1897. Described as *Stromatinia temulenta* P. & Del. The conidial stage is described as *Endoconidium temulentum* Pr. & Del.

Seed fungus (See RYE GRASS)

Tilletia tritici (Bjerk.) Wint. *Bunt* or *stinking smut of wheat*

Gaines, E. F., & F. J. Stevenson. Phytopath. *13:* 210-215. 1923. It is suggested that *Tilletia secalis* is probably this species, which only rarely infects rye.

**Tilletia secalis* (Corda) Kuehn. *Stinking smut of rye* (See TILLETIA TRITICI)

Tylenchus tritici (Stein.) Bast. *Nematode* (See WHEAT)

Urocystis occulta (Wall.) Rab. *Flag smut*

Tisdale, W. H., & V. F. Tapke. U. S. Dept. Agr. Farmers' Bul. 1540. 1927.
Wolff, R. Bot. Zeit. *31:* 657, 673, 689. 1873.

Ustilago tritici (Pers.) Rostr. *Loose smut of wheat*

Tisdale, W. H., & V. F. Tapke. U. S. Dept. Agr. Farmers' Bul. 1540. 1927.

RYE GRASS *(Lolium* spp.)

Seed fungus (See DARNEL)

Freeman, E. M. Roy. Soc. (London) Phil. Trans. (B) *196:* 1-27. 1903.

Jodidi, S. L., & J. Peklo. Jour. Agr. Res. *38:* 69-91. 1929.
Occurs also in wheat, rye, and barley. This organism is probably a smut of the type of *Ustilago tritici.*

SALSIFY *(Tragopogon porrifolius)*

Albugo tragopogonis (DC.) SFG. *White rust*

Heald, F. D. Trans. Am. Microscop. Soc. *32:* 9. 1913.
"The seed of the oyster plant may be so badly infested with the white rust as to entirely destroy the crop."

SCARLET RUNNER BEAN *(Phaseolus multiflorus)*

Phytomonas medicaginis var. *phascolicola* Burk. *Wilt* and *halo blight*

Burkholder, W. H. Phytopath. *16:* 915-927. 1926. Also on common bean and lima bean.

SESAMUM *(S. orientale)*

**Fusarium* sp. *Wilt*

Stevenson, J. A. U. S. Dept. Agr. For. Pl. Dis. 169. 1926. A serious disease in India.

SNAPDRAGON *(Antirrhinum majus)*

Phyllosticta antirrhini Syd. *Leaf-spot; stem rot*

Buddin, W., & E. M. Wakefield. Gard. Chron. (London) *76:* 150-151. 1924.
Transmitted on diseased capsules included with seed; probably also on seed.

SOJA MAX = SOYBEAN

SORGO (See SORGHUM)

SORGHUM

(Holcus sorghum L., *Andropogon sorghum,* including the varieties known as broom corn, darso, durra, feterita, hegari, Indian millet, kafir, kaoliang, milo, sorgo, Sudan grass, and Sudan corn)

Bacterium andropogoni EFS. *Bacterial stripe*

Elliott, Charlotte, & E. F. Smith. Jour. Agr. Res. *38:* 1-22. 1929. Strongly suspected of being seed-borne, but full proof lacking. Hosts are broom corn, feterita, Sudan grass, and corn.

Bacterium holci Kend. *Holcus bacterial-spot*

Kendrick, J. B. Iowa Agr. Exp. Sta. Res. Bul. 100. 1926.
The disease also attacks Johnson grass, broom corn, Sudan grass, pearl millet, foxtail, and dent, flint, sweet, and pop corn in addition to 22 varieties of sorghum types. Seed transmission was demonstrated in 11 varieties of sorghum of the red amber, white milo, hegari, kafir, and feterita types. It is probable that all of the hosts here listed may carry infection of the bacterium in the seed, although the results with corn are considered negative.

Bacterium holcicola Elliott. *Bacterial streak*

Elliott, C. Jour. Agr. Res. *40:* 963-976. 1930. Believes the organism to be spread by seed.

Fusarium moniliforme Sheldon. *Root rot*

Valleau, W. D. Ky. Agr. Exp. Sta. Bul. 226. 1920.

Phoma insidiosa F. Tass. *Leaf spot*

Koch, Elizabeth, & Caroline Rumbold. Phytopath. *11:* 253-268. 1921. A generally prevalent disease wherever the host is grown.

Sclerospora graminicola (Sacc.) Schroet. *Downy mildew* (See MILLET)

Sorosporium reilianum (Kuehn) McAlpine. *Head smut*

Hori, S. Bul. Imp. Con. Agr. Exp. Sta. Japan, *1:* 163-166. 1907.

Potter, A. A. Jour. Agr. Res. *2:* 339-371. 1914. Known to infect durra varieties, sorgho varieties, sorghum, and corn. Soil infestation usual source of infection but the spores must be carried with the seed at times in order to account for the distribution of this smut.

Sphacelotheca cruenta (Kuehn) Potter. *Loose kernel-smut*

Potter, A. A. Phytopath. *5:* 149-154. 1915.

Sphacelotheca sorghi (Link) Clinton. *Covered kernel-smut*

Known to infect broom corn, durra, feterita, kafir, kaoliang, sorgo, Sudan grass, shallu, milo, etc. Of these suscepts, milo, feterita, darso, dwarf hegari, and Sudan corn are highly resistant.

Clinton, G. P. Ill. Agr. Exp. Sta. Bul. 47. 1897.

———— Ill. Agr. Exp. Sta. Bul. 57. 1900.

Kellerman, W. A. Kans. Agr. Exp. Sta. Bul. 23: 95. 1891.

Reed, G. M., & L. E. Melchers. U. S. Dept. Agr. Bul. 1284: 2-5. 1925.

Soy Bean *(Soja, Glycine)*

Bacillus lathyri Manns & Taub. (See ALFALFA)

Bacterium glycineum Coerper. *Bacterial blight*

Coerper, Florence M. Jour. Agr. Res. *18:* 179-194. 1919.

Kendrick, J. B., & M. W. Gardner. Phytopath. *11:* 340-342. 1921.

Wolf, F. A. Phytopath. *10:* 119-132. 1920.

Only seed from disease-free pods should be planted.

Bacterium glycineum var. *japonicum* (Tak.) Elliott

Takimoto, S. Jour. Plant Prot. (Tokyo) *14:* 559-566. 1927. The disease is similar to that caused by *B. glycineum*. Spots on pods brownish to blackish and sunken. Not proved to be seed-borne but highly probable.

Bacterium phaseoli EFS. *Bean blight* (See BEANS)

Bacillus phaseoli sojense Hedges. *Bacterial pustule*

Lehman, S. G. Jour. Agr. Res. *39:* 795-805. 1929.

Wolf, F. A. Jour. Agr. Res. *29:* 57-68, 229-251. 1924.

Columbia variety most resistant of 40 var. tested. The disease is also known on lima and garden beans.

Bacterium sojae Wolf = *B. glycineum*

Cercospora diazu Miura. *Frog-eye spot*

Lehman, S. G. Jour. Agr. Res. *36:* 811-833. 1928.

**Cercosporina kikuchii* Mats. & Tom. *Leaf spot*

Matsumoto, T., & R. Tomoyasu. Ann. Phytopath. Soc. Japan *1*[6]*:* 1-14. 1925.

Fusarium sp. Relation to field symptoms undetermined

Chen, C. C. Md. Agr. Exp. Sta. Bul. 240: 98. 1920.

Macrosporium sp. Relation to field symptoms undetermined

Chen, C. C. Md. Agr. Exp. Sta. Bul. 240: 98. 1920.

Mosaic (Virus)

Gardner, M. W.. & J. B. Kendrick. Jour. Agr. Res. *22:* 111-114. 1921.
Kendrick, J. B., & M. W. Gardner. Jour. Agr. Res. *27:* 91-98. 1924.

Peronospora manshurica (Naoum.) Syd. = *P. sojae* Wolf

Peronospora sojae Wolf. *Downy mildew*

Wolf, F. A. Jour. Elisha Mitchell Soc. *39:* 164-169. 1924.
———— & S. G. Lehman. No. Car. Agr. Exp. Sta. Report *49* (1924): 82-85. 1925.

Phomopsis sojae Lehman. *Pod* and *stem blight*

Lehman, S. G. Jour. Elisha Mitchell Soc. *38:* 13. 1922. The causal fungus penetrates the pod wall and invades the developing seed.

Sclerotinia libertiana Fuckel = *S. sclerotiorum* (Lib.) Mass. *Sclerotium disease*

Pape, H. Mitteil. Biol. Reichs. f. Land. Först. *21:* 36-42. 1921.

Septoria glycines Hemmi. *Brown spot*

Wolf, F. A., & S. G. Lehman. Jour. Agr. Res. *33:* 365-374. 1926. Disease probably imported on seed from Japan.

Spurge (*Euphorbia* spp.)

Uromyces dictyosperma Ellis & Ev. *Rust*

Mains, E. B. Proc. Ind. Acad. Sci. *1921:* 137-139. 1922. Exact method of transmission unknown but author suggests external by spores, possibly teliospores. On *Euphorbia arkansana.*

Uromyces proeminens (DC) Pass. *Rust*

Carleton, M. A. U. S. Dept. Agr. Bur. Pl. Ind. Bul. 63: 9-11. 1904.
Mains, E. B. Proc. Indiana Acad. Sci. *1921:* 137-139. 1922. Exact method of transmission unknown but author suggests externally-borne spores, possibly teliospores. On *Euphorbia dentata.*

Stizolobium = velvet bean

Stock (*Matthiola incana annua*)

Bacterium matthiolae Briosi. *Bacteriosis*

Briosi, G., & L. Pavarino. Atti R. Inst. Bot. Univ. Pavia Ser. 2. *15:* 135-141. 1912. Authors recommend seed treatment with mercuric chloride.

Phoma lingam (Tode) Desm. *Black leg* (See cabbage)

Stramonium (*Datura stramonium*)

Mosaic (Virus)

Blakeslee, A. F. Proc. Nat. Acad. Sci. *7:* 116-118. 1921.
———— Jour. Genetics *11:* 17-36. 1921. Transmitted through pollen to seed of 79% of offspring.

Strawberry Tree (*Arbutus unedo*)

Endotrophic mycorrhiza

Raymer, M. C. Ann. Bot. *29:* 97-133. 1915.
———— New Phytol. *25:* 185. 1926. Ovarial infection recorded.

Sudan Corn (See sorghum)

Sudan Grass (See sorghum)

Sugar Beet (See beet)

Sunflower (*Helianthus* spp.)

Plasmopara halstedii (Farl.) Berl. & deToni. *Downy mildew*

Young, P. A., & H. E. Morris. Am. Jour. Bot. *14:* 551-552. 1927. Complete proof lacking, but evidence points to the overwintering of the fungus in the seed.

Sclerotinia sclerotiorum (Lib.) Mass. *Stem-rot*

Drayton, F. L. Dominion of Canada P. D. S. 40. 1923.

Young, P. A., & H. E. Morris. Mont. Agr. Exp. Sta. Bul. 208. 1927. Large numbers of sclerotia are carried with seed, from which they are difficult to separate.

Swedes (*Brassica campestris*)

Alternaria sp. *Seed fungus*

Cunningham, G. H. New Zealand Dept. Agr. Bul. 133. 1927. Reported as common on swedes and turnip seed. Probably same fungus as Chupp reports on cabbage.

Phoma lingam (Tode) Desm. *Black leg* (See cabbage and turnip also)

Cunningham, G. H. New Zealand Dept. Agr. Bul. 133. 1927.

Sweet Alyssum (*Alyssum* spp.)

Phoma lingam (Tode) Desm. *Black leg* (See cabbage)

Sweet Corn (See corn)

Sweet Clover (*Melilotus alba*)

Mosaic (Virus)

Dickson, B. T. McDonald College Tech. Bul. 2: 85-86. 1922.

Sweet Pea (*Lathyrus odoratus*)

Bacillus lathyri Manns & Taub. *Streak* (See alfalfa)

Bacterium pisi (Sack.) EFS. *Bacterial blight of peas* (See pea)

Glomerella rufomaculans (Berk.) Sp. & v. Schrenk. *Bitter rot*

Taubenhaus, J. J. Del. Agr. Exp. Sta. Bul. 106: 1-93. 1914. The fungus attacks the pods universally and overwinters upon them. It is inferred that the disease is seed-borne, but final proof seems lacking.

Sweet William (*Dianthus barbatus*)

Puccinia dianthi DC. *Rust*

Cooke, M. C. Fungoid Pests of Cultivated Plants, 34. 1906. Plants grown from Japanese seed developed this rust in England.

Teasel (*Dipsacus fullonum*)

Tylenchus dipsaci Kuehn. *Stem nematode*

Kuehn, J. Zeitschr. Wiss. Zool. *9:* 129-132. 1858.

Teosinte (*Euchlaena mexicana*)

(See *Sclerospora graminicola* under millet)

Tick Trefoil *(Desmodium; Meibomia)*

Bacterium vignae Gard. & Kend. *Bacterial spot of cowpea* (See cowpea)

Timothy *(Phleum pratense)*

Colletotrichum graminicolum (Ces.) Wils. *Anthracnose* (See wheat)

Ustilago striaeformis (Westd.) Niessl. *Leaf smut*

Osner, G. A. N. Y. (Cornell) Agr. Exp. Sta. Bul. 381: 189-230. 1916. Modified hot-water treatment effective.

Tobacco *(Nicotiana* spp.)

Bacterium angulatum Fromme & Murray. *Angular leaf-spot*

Fromme, F. D., & T. J. Murray. Jour. Ag. Res. *16:* 219-228. 1919.
———— Va. Poly. Inst. Ext. Bul. 62. 1920.
———— & S. A. Wingard. Va. Agr. Exp. Sta. Tech. Bul. 25. 1922.

Bacterium melleum Johns. *Bacterial leaf-spot*

Johnson, J. Jour. Agr. Res. *23:* 481-494. 1923.
———— Wis. Agr. Exp. Sta. Bul. 373: 5-16. 1925.

Bacterium tabacum Wolf. *Wild-fire*

Clinton, G. P., & F. McCormick. Conn. Agr. Exp. Sta. Bul. 203: 67-81. 1921.
Fromme, F. D. Va. Poly. Inst. Ext. Bul. 62. 1920.
Johnson, J., C. M. Slagg, & H. F. Murwin. Phytopath. *14:* 175-180. 1924.
Wolf, F. A. No. Car. Agr. Exp. Sta. Bul. 246: 13, 18. 1922.
Natural infection occurs also on tomato, *Petunia hybrida, Phytolacca decandra, Solanum melongena,* and *Vigna sinensis.* Artificial infection occurred on a wide range of plants, embracing 21 different families. Seed transmission proved only with tobacco.

Peronospora hyoscyami de Bary. *Blue mold; downy mildew*

Angell, H. R. Jour. Council Sci. & Ind. Res. Australia (Reprint p. 1-5). 1929. Diseased seedlings appear only in certain lots of seed, but actual proof of seed carriage not fully demonstrated.

Phytomonas polycolor Clara. *Philippine bacterial leaf-spot*

Clara, F. M. Phytopath. *20:* 691-706. 1930. Infection from seed reduced by disinfection in silver nitrate (1-1000) for 10-15 minutes.

Ring spot (Virus)

Valleau, W. D. Plant Dis. Rep. *14:* 113. 1920.
Evidence that this disease is seed-borne in a small percentage of cases on Turkish tobacco.

Tomato *(Lycopersicum esculentum)*

Aplanobacter michiganense EFS. *Bacterial canker* or *Grand Rapids disease*

Bryan, Mary K. U. S. D. A. Circ. 29. 1928.
———— Jour. Agr. Res. *41:* 825-851. 1930. The causal bacteria are disseminated on and in the seed. Absolutely clean seed can be obtained only by selection from disease-free fields. Surface infection is eliminated by disinfection with organic mercury dusts and is to be recommended when the seed is not known to be absolutely disease-free.

Bacillus lathyri Manns & Taub. (?) *Winter blight, stripe, streak*

Berkeley, G. H. Ontario Dept. Agr. Ann. Rept. Veg. Growers' Assoc. *25:* 52-59. 1930. Demonstrated streak as seed-borne.

Dickson, B. T. Science *62:* 398. 1925.

Doolittle, S. P., & H. L. Blood. Phytopath. *20:* 134. 1930.

Orton, C. R. Proc. Am. Seed Trade Assoc. *40:* 74-82. 1922.

Paine, S. G., & W. F. Bewley. Ann. Appl. Biol. *6:* 183-202. 1919.

Vanterpool, T. C. Phytopath. *16:* 311-331. 1926.

Considerable confusion still exists regarding the nature of the destructive tomato diseases which have been variously designated under the common names appearing above. The disease in England was attributed by Paine and Bewley to *B. lathyri.* In North America various workers have reproduced certain types of the disease by virus mixtures with potato virus. There are at least three distinct types of this disease which have been confused in the literature and by the various workers. The type of this disease occurring in Pennsylvania was proved to be seed-borne by Orton in 1917 and thereafter. At least one type of the disease has become almost world-wide in distribution during recent years. See reference by Orton. One type of the disease is infrequently seen in epiphytotic conditions in the field. Most frequently these maladies are restricted to glass-house tomatoes. Some of the literature appears to be confused with Grand Rapids disease.

Bacterium leguminiperdum v. Oven (See BEANS)

**Bacterium lycopersici* Burgw. *Blossom end-rot bacteriosis*

Burgwitz, G. K. Morbi Plant. (Leningrad) *13:* 128-130. 1924. The relation of this disease to the blossom end rot occurring in No. America is uncertain.

Bacterium exitiosum Gard. & Kend. = *B. vesicatorium*

Bacterium vesicatorium Doidge. *Canker*

Doidge, Ethel. Jour. Dept. Agr. Union So. Africa *1:* 718-721. 1920.

———— Ann. Appl. Biol. *7:* 407-430. 1921.

Gardner, M. W., & J. B. Kendrick. Jour. Agr. Res. *21:* 123-156. 1921.

The disease has been recorded upon many varieties of tomatoes. The pathogen also attacks *Capsicum annuum, Datura stramonium, Hyoscyamus niger, H. aureus, Lycium* spp., *Nicotiana rustica, Physalis minima, Solanum dulcamara, S. nigrum, S. rostratum* and *S. tuberosum.* It is seed-borne on tomato and pepper and probably on some of its other hosts.

Cladosporium fulvum Cooke. *Leaf mold*

Gardner, Max W. Indiana Acad. Sci. *1924:* 311. 1925.

———— Jour. Agr. Res. *31:* 536-538. 1925.

Colletotrichum phomoides (Sacc.) Chester. *Anthracnose*

Harvey, F. L. Maine State Coll. Ann. Rept. *1893:* part II, 152.

Pritchard, F. J. The Canning Trade *46:* 33-34. 1923.

Fusarium lycopersici Sacc. *Wilt*

Clinton, G. P. Conn. Agr. Exp. Sta. Rept. *1903:* part 4, 279-370.

Edgerton, C. W., & C. C. Moreland. La. Agr. Exp. Sta. Bul. 174: 54. 1920.

Elliott, J. A., & R. A. Crawford. Phytopath. *12:* 428-434. 1922.

Macrosporium solani E. & M. *Early blight*

Massee, I. Bul. Agr. Intel. & Plant Dis. *5:* 1518-1519. 1914.

Roy. Bot. Gard. Kew Bul. Miscell. Inf. 4: 145-146. 1914.

Nematospora lycopersici Schneid.

Schneider, A. Phytopath. *6:* 395-399. 1916. Seed infection occurs but seed transmission not proved, although probable.

Phoma destructiva Plow. *Fruit rot*

Link, G. K. K., & F. C. Meier. U. S. Dept. Agr. Cir. 219: 1-5. 1922. (See PEPPER also.)

Phytophthora omnivora de Bary. *Brown rot; "buckeye" rot*

Bancroft, C. K. Jour. Bd. Agr. (London) *16:* 1012. 1910. Claims that the hyphae penetrate endosperm and embryo of seed and that such infested seeds germinate and always produce infected fruits.

Rhizopus nigricans Ehr. *Seedling blight*

Chen. C. C. Md. Agr. Exp. Sta. Bul. 240: 104. 1920.

Trailing Wild Bean *(Strophostyles helvola)*

Bacterium phaseoli EFS. *Bacterial blight of bean* (See bean)

Trifolium pratense = red clover

Turnip *(Brassica rapa)*

Alternaria sp. *Seed fungus* (See swedes)

Bacterium campestre (Pamm.) EFS. *Black rot* (See cabbage)

Mycosphaerella brassicicola (Fr.) Lindau. *Ring spot* (See broccoli)

Infects yellow but not white varieties of turnips.

Phoma lingam (Tode) Desm. *Black leg* (See cabbage also.)

Cunningham, G. H. New Zeal. Dept. Agr. Bul. 133. 1927. Destructive also on swedes in New Zealand. Pathogen is present in seedcoats, from which it spreads to developing cotyledons, where infection results and fruit bodies form. Seed disinfection for 1 hour in 0.25 percent chlor-phenol mercury at 46°C. was completely effective without causing material damage to seed.

Velvet Bean *(Stizolobium deeringeanum)*

Bacterium phaseoli EFS. *Bean blight* (See bean)

Bacterium vignae Gard. & Kend. *Bacterial spot* (See cowpea)

Vetch *(Vicia* spp.)

Bacterium vignae Gard. & Kend. (See cowpea)

Protocoronospora nigricans A. K. & Edg. *False anthracnose*

Wolf, F. A. Jour. Elisha Mitchell Soc. *36:* 72-84. 1920. Attacks *Vicia sativa, V. villosa, V. angustifolia, & V. dasycarpa.*

Vicia = vetch

Violet *(Viola* spp.)

Urocystis violae (Sow.) F. von Wald. *Smut*

Pape, H. Centralb. f. Bakt. Parasit. u. Inf. II: *65:* 301-307. 1925.

Walnut *(Juglans* spp.)

Bacterium juglandis (Pierce) EFS. *Bacteriosis* (See black walnut)

Watermelon *(Citrullus vulgaris)*

Alternaria cucurbitae Let. *Leaf blight*

Munn, M. T. Proc. Assoc. Off. Seed Analysts *12-13:* 57-59. 1921.

Colletotrichum lagenarium (Pass.) Ellis & Hals. (See cucumber)

Fusarium niveum EFS. *Fusarium wilt*

Fulton, H. R. No. Car. Agr. Exp. Sta. Bien. Rept. *1913-14:* 48-51. 1914. Spores carried externally. Seed disinfection effective with mercury compounds.

Western Rye Grass *(Agropyron tenerum)*

Ustilago bullata Berk. *Loose smut*

Fraser, W. P., & G. A. Scott. Phytopath. *16:* 473-477. 1926. Reported as *U. bromivora.* Controlled by formaldehyde seed treatment.

Muraschinsky, K. E. p. 4 Omsk. 1926. [See Biol. Abs. *2:* (404) 1928.] Believed to have been introduced into Russia from North America.

Wheat *(Triticum aestivum)*

Acrostalagmus sp. Isolated from seed but only slightly pathogenic to seedlings

Henry, A. W. Minn. Agr. Exp. Sta. Tech. Bul. 22: 12-13, 21. 1924.

Alternaria sp. Relation to field symptoms undetermined; a very common fungus on wheat seed

Bolley, H. L. Ann. Rept. No. Dakota Agr. Exp. Sta. *22:* 3-40. 1912.

———— No. Dak. Agr. Exp. Sta. Bul. 107: 1-94. 1913.

Henry, A. W. Minn. Agr. Exp. Sta. Tech. Bul. 22: 1-71. 1924. Finds *Alternaria* generally pathogenic to wheat seedlings.

Stakman, Louise J. Univ. of Minn. Studies in Biol. Sci. No. 4: 139-161. 1923.

Wollenweber, H. W. Jour. Agr. Res. *2:* 251-285. 1914.

**Alternaria tenuis* Nees. *Black point;* see also CLADOSPORIUM HERBARUM and BRACHYSPORIUM sp.

Peyronel, B. Boll. R. Staz. Pot. Veg. (Roma) *6* (1): 10-25. 1926. Isolated *A. tenuis* frequently from black pointed seeds and occasionally *Cladosporium herbarum.* He concludes that the latter organism is not always the cause of "black point". Comparison of *A. tenuis* with *Alternaria* sp. as listed above should be made.

Aspergillus niger van Tieg. Relation to field symptoms undetermined; caused a root disease of seedlings in greenhouse at Minnesota.

Henry, A. W. Minn. Agr. Exp. Sta. Tech. Bul. 22: 45. 1924.

Bacterium atrofaciens McCul. *Basal glume-rot*

McCulloch, Lucia. Jour. Agr. Res. *18:* 543-552. 1920. Infection of kernels proved, but it is not yet demonstrated that infected kernels produce infected plants though the distribution of the disease indicates such manner of infection.

Bacterium cerealinum (Gentner) Elliott. *Bacteriosis* (See BARLEY)

Bacterium translucens var. *undulosum* Sm., Jones & Reddy. *Black chaff*

Braun, H. Jour. Agr. Res. *19:* 363-392. 1920.

Reddy, C. S., J. Godkin, and A. G. Johnson. Jour. Agr. Res. *28:* 1039-1040. 1924.

Smith, E. F. Jour. Agr. Res. *10:* 51-53. 1917.

Smith, E. F., L. R. Jones, & C. S. Reddy. Science *50:* 48. 1919.

Bacterium tritici (Hutch.) Elliott. *Punjab* or *Tandu disease*

Carne, W. M. Jour. Dept. Agric. West. Austr. *3* (ser. 2): 508-512. 1926.

Fahmy, T. E., & T. E. Mikhail. Agric. Jour. Egypt. New Ann. ser. 1923. *1:* 64-72. 1925.

Hutchinson, C. M. Mem. Dept. Agric. India Bact. ser. *1:* 169-175. 1917. Eelworms thought by Fahmy and Carne to be associated with the bacteria and responsible for their introduction into the host plant.

Brachysporium sp. *Black point*

Henry, A. W. Phytopath. *13:* 49. 1923. See *Helminthosporium M.*
———— Minn. Agr. Exp. Sta. Tech. Bul. 22: 36-37. 1924. The relations of *Brachysporium* to *Helminthosporium M.* in this case are not yet understood.

Calonectria graminicola (Berk. & Br.) Wr. = *Fusarium nivale*

Cephalosporium sp. Isolated from wheat seed at Minn. Exp. Sta. but pathogenicity not yet established

Henry, A. W. Minn. Agr. Exp. Sta. Tech. Bul. 22: 12. 1924.

Cephalothecium roseum Corda. *Pink mold*

Bolley, H. L. Ann. Rept. No. Dak. Agr. Exp. Sta. *22:* 3-40. 1912. Isolated from wheat seed at North Dakota and Minnesota stations but apparently not pathogenic to wheat seedling in Minnesota tests.

Chaetomium sp.

Henry, A. W. Minn. Agr. Exp. Sta. Tech. Bul. 22: 21. 1924. Isolated from wheat seeds at Minn. Exp. Sta. but pathogenicity not yet established. In one trial it did not prove to be pathogenic.

Cladosporium gramineum Corda.

Board of Agric. & Fisheries, London, Leaflet 289: 1-2. 1915. Reduces germination. Recommends seed testing and rejection of poor seed.
Henry, A. W. Minn. Agr. Exp. Sta. Tech. Bul. 22: 12, 30. 1924. Isolated from wheat seed but did not prove pathogenic in two tests.

Cladosporium herbarum (Pers.) Link = *Mycosphaerella tulasnei. Black point* (See RYE)

Claviceps purpurea (Fries) Tul. *Ergot* (See RYE)

Colletotrichum graminicolum (Ces.) Wilson. *Anthracnose*

Bolley, H. L. Ann. Rept. No. Dak. Agr. Exp. Sta. *22:* 3-40. 1912.
———— No. Dak. Agr. Exp. Sta. Bul. 107: 1-94. 1913.
Selby, A. D., & T. F. Manns. Ohio Agr. Exp. Sta. Bul. 203. 1909.

Dilophospora alopecuri Fries. *Dilophospora disease*

Atanasoff, D. Phytopath. *15:* 11-40. 1925. Carried with the seed in the galls, which also bear *Tylenchus tritici* (Stein.) Bast. These galls may be removed by the saturated salt solution method. Also attacks rye.

Epicoccum sp.

Henry, A. W. Minn. Agr. Exp. Sta. Tech. Bul. 22: 21. 1924. Isolated from wheat seed at Minn. Agr. Exp. Sta. but not apparently pathogenic to seedlings in two trials.

Fusarium avenaceum (Fr.) Sacc. = *F. subulatum*

Fusarium culmorum (W. G. Sm.) Sacc. A scab and seedling blight fungus frequently confused in the early literature with the conidial stage of *Gibberella saubinetii*

Stakman, Louise J. Univ. of Minn. Studies Biol. Sci. No. 4: 139-161. 1923.
Wollenweber, H. W. Jour. Agr. Res. *2:* 251-285. 1914.

Fusarium graminearum Schwabe = *Gibberella saubinetii*

Fusarium herbarum (Corda) Fries. Isolated from wheat seed in Germany but relation to field symptoms not determined so far as compiler knows

Wollenweber, H. W. Jour. Agr. Res. *2:* 251-285. 1914.

Fusarium metachroum App. & Wollenw. = *F. herbarum*

Fusarium moniliforme Sheldon. *Root rot*

Henry, A. W. Minn. Agr. Exp. Sta. Tech. Bul. 22: 28-33. 1924. The fungus is common on corn in the United States.
Shcrbakoff, C. D. Phytopath. *12:* 19. 1922.

Fusarium nivale Ces. *Foot rot* and *seedling blight*, especially of *rye*

Atanasoff, D. Jour. Agr. Res. *20:* 1-32. 1920. Reports the disease in U. S. A.
Schaffnit, E. Landw. Jahrb. *43:* 521-648. 1913.
Perfect stage is *Calonectria graminicola.*

**Fusarium subulatum* App. & Wollenw. Isolated from wheat seed in Germany, where it is said to cause head-blighting and seedling blight

Naumov, N. A. Minn. Zeml. (Russia) Trudy Biûro Mykol. i. Fitopat. Uchen. Kom. No. 12. 1-216. 1916.
Wollenweber, H. W. Jour. Agr. Res. *2:* 251-285. 1914.

Fusarium spp. *Root rots* and *seedling blights*

Bolley, H. L. Ann. Rept. No. Dak. Agr. Exp. Sta. *22:* 3-40. 1912.
Henry, A. W. Minn. Agr. Exp. Sta. Tech. Bul. 22: 21, 33. 1924.
Hoffer, G. N. Proc. Ind. Acad. Sci. *1913:* 97-98. 1914.
Stakman, Louise J. Univ. of Minn. Studies Bot. Sci. No. 4: 139-161. 1923.
It seems probable that most of these reports refer to species listed above.

Gibberella saubinetii (Mont.) Sacc. *Seedling blight, scab*

Atanasoff, D. Jour. Agr. Res. *20:* 1-32. 1920.
Selby, A. D., & T. F. Manns. Ohio Agr. Exp. Sta. Bul. 203, 212-236. 1909.
A common and widely distributed disease of cereals in North America. (See also BARLEY, CORN, and RYE.)

Helminthosporium sativum P. K. & B. *Black point* and *foot rot*

Evans, N. S. Phytopath. *12:* 34. 1922.
Henry, A. W. Minn. Agr. Exp. Sta. Tech. Bul. 22: 33-36. 1924.
Stakman, Louise J. Minn. Agr. Exp. Sta. Bul. 191: 1-18. 1920.
Weniger, Wanda. Phytopath. *13:* 48-49. 1923.

Helminthosporium M. Root rot and *black point* (See *Brachysporium)*

Henry, A. W. Minn. Agric. Exp. Sta. Tech. Bul. 22: 36-42. 1924. Isolated four strains of this species which differ morphologically and physiologically.

Helminthosporium N. Root rot and *black point*

Henry, A. W. Minn. Agr. Exp. Sta. Tech. Bul. 22: 34-36. 1924. Similar to *Podosporiella verticillata* in conidial features.

**Langloisula* sp.

Wollenweber, H. W. Jour. Agr. Res. *2:* 252. 1914. Associated with carmine red spots on wheat seeds in Germany.

**Leptosphaeria* sp.

Wollenweber, H. W. Jour. Agr. Res. *2:* 252. 1914. Isolated from seed in Germany but field symptoms not established.

Macrosporium spp. Isolated from seed but field symptoms not established

Bolley, H. L. Ann. Rept. No. Dak. Agr. Exp. Sta. *22:* 3-40. 1912.
———— No. Dak. Agr. Exp. Sta. Bul. 107: 1-94. 1913.
Hoffer, G. N. Proc. Ind. Acad. Sci. *1913:* 97-98. 1914.

**Melanospora* sp.

Wollenweber, H. W. Jour. Agr. Res. *2:* 252. 1914. Isolated from seed in Germany but field symptoms not established.

Ophiobolus cariceti (Berk & Br.) Sacc. = *O. graminis* Sacc. *Take-all.*

Brittlebank, C. C. Jour. Dept. Agr. Victoria *19:* 447. 1921. The perithecia may be carried on bits of straw with the seed. Only indirect evidence that this fungus is carried with the seed.

Penicillium sp.

Henry, A. W. Minn. Agric. Exp. Sta. Tech. Bul. 22: 12, 21. 1924. Isolated from seed wheat but only in one of four tests did it prove pathogenic.

Podosporiella verticillata O'Gara

O'Gara, P. J. Phytopath. *5:* 323-326. 1915. Not considered parasitic but seriously impairs the germinating kernels.

Puccinia graminis Pers. *Stem rust*

Pritchard, F. J. Phytopath. *1:* 150-154. 1911. Mycelium from pericarp penetrates various parts of the seedling. Others dispute seed transmission of stem rust.

**Ramularia* sp.

Wollenweber, H. W. Jour. Agr. Res. *2:* 252. 1914. Isolated from seed in Germany but field symptoms not established.

Sclerospora macrospora Sacc. *Downy mildew*

Peglion, V. Abstract in Centralbl. f. Bakt. *26:* 108. 1910. Mycelium infects young ovaries and develops within pericarp. Infection of seedlings results from planting seed which is apparently healthy.

Seed fungus (See RYE GRASS)

Septoria nodorum Berk. *Glume spot*

Rosen, H. R. Ark. Agr. Exp. Sta. Bul. 175. 1921. Rosen has not demonstrated the seed dissemination of this disease but from the sticky character of the exuding cirrus of spores it appears very probable that they are carried on the seed.

**Spicaria* sp.

Wollenweber, H. W. Jour. Agr. Res. *2:* 252. 1914. Isolated from seed in Germany but field symptoms not established.

Stemphylium parasiticum (Thum.) Elliot

Henry, A. W. Phytopath. *13:* 49. 1923. Apparently the same as *Macrosporium parasiticum,* and according to Miyabe, *Pleospora herbarum* is the perfect stage.
———— Minn. Agr. Exp. Sta. Tech. Bul. 22: 43. 1924.

Tilletia laevis Kuehn. *Smooth-spored bunt* or *stinking smut*

Kuehn, J. Hedwigia *2:* 5. 1858.

Tilletia tritici (Bjerk) Wint. *Rough-spored bunt* or *stinking smut*

Gleichen. Auserlesene mikrosk. Entdeckungen p. 46. 1781.
McAlpine, D. The Smuts of Australia, 70-85. 1910.
Schulthess. Abhandl. Naturf. Gesell. Zürich. *1:* 498-506. 1761.
Tessier, H. A. Paris. 1783.

Gleichen was apparently the first to show experimentally that bunt is carried on the seed and that moisture is essential to infection. The species with which he worked is doubtful, though *T. tritici* is probably the most common European bunt. This species is much more inclined to live over winter in the soil in the United States than the preceding, to which it is closely related. Schulthess was apparently the first to test the effect of copper sulphate on wheat for smut control in 1761, and Tessier in 1783 and 1786 found copper sulphate to be effective in controlling bunt.

Torula sp.

Henry, A. W. Minn. Agr. Exp. Sta. Tech. Bul. 22: 12, 20. 1924.
Isolated from seed but not pathogenic to wheat seedlings in two tests.

Trichoderma sp.

Henry, A. W. Minn. Agr. Exp. Sta. Tech. Bul. 22: 13, 31, 45. 1924.
Two species isolated from seed, one of which proved slightly parasitic on seedlings.

**Trichothecium* sp.

Wollenweber, H. W. Jour. Agr. Res. *2:* 252. 1914.
Isolated from seed in Germany but field symptoms not established.

Tylenchus tritici (Stein.) Bast. *Nematode disease*

Byars, L. P. U. S. D. A. Farmers' Bul. 1041: 1-10. 1919.
Fromme, F. D. Va. Agr. Exp. Sta. Bul. 222. 1919. Not intraseminal but occurs in galls which replace the seed.

Urocystis tritici Koern. *Flag smut*

Brittlebank, C. C. Jour. Dept. Agr. Victoria *19:* 447. 1921.
Hori, S. Bul. Imp. Cent. Agr. Exp. Sta. *1:* 163-176. 1907.
McAlpine, D. The Smuts of Australia, 88-102. 1910.
This smut acts much like *T. tritici* in its persistence in the soil, especially on straw and other plant debris.

Ustilago tritici (Pers.) Rostr. *Loose smut*

Barrus, M. F. Proc. Ind. Acad. Sci. *1908:* 113-122. 1909.
Brefeld, O., & R. Falck. Unters. Gesam. Geb. Mykol. No. 13. 1905.
Hecke, L. Zeitschr. f. Landwirtsch. Versuch. Oesterr. *7:* 59-64. 1904.
Maddox, F. Dept. of Agr. Tasmania. 1895.
———— Notes and Results of Agricultural Experiments. Launceston, Tasmania, 1897.
Maddox was the first to demonstrate floral infection by the smut fungi.

**Verticillium* sp.

Wollenweber, H. W. Jour. Agr. Res. *2:* 252. 1914. Isolated from seed in Germany but field symptoms not established.

Wheat Grass *(Agropyron Smithii* & *Apropyrum* spp.)

Aplanobacter agropyri O'Gara

O'Gara, P. J. Phytopath. *6:* 341. 1916.

White Cedar = arbor vitae

White Clover *(Trifolium repens)*

Bacterium trifoliorum Jones, Will., Wolf, & McCull. (See alsike clover)

**Sclerotinia* sp. resembling *S. trifoliorum* but with smaller apothecia

Alcock, N. L., & M. S. Martin. Trans. & Proc. Bot. Soc. Edinburgh *30:* 13-18. 1928. Infects seed and mycelium develops under seedcoat. First detected in shipments of seed from New Zealand to Scotland.

Sphaerulina trifolii Rostr. *Sphaerulina leaf-spot* (See red clover)

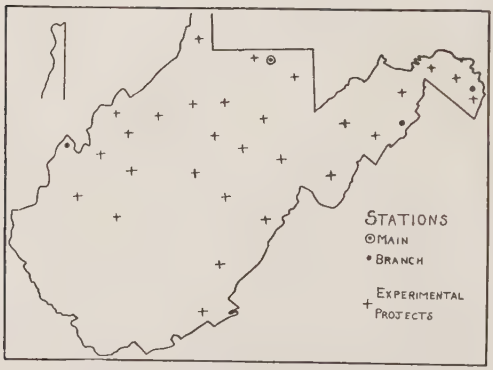
Wild Cucumber *(Micrampeltis lobata)*

Mosaic (Virus)

Doolittle, S. P., & W. W. Gilbert. Phytopath. *9:* 326. 1919.
———— Phytopath. *11:* 47. 1921.
———— & M. N. Walker. Jour. Agr. Res. *31:* 1-58. 1925.

Wild Rye *(Elymus* spp.) (See grasses)

AGRICULTURAL EXPERIMENT STATION



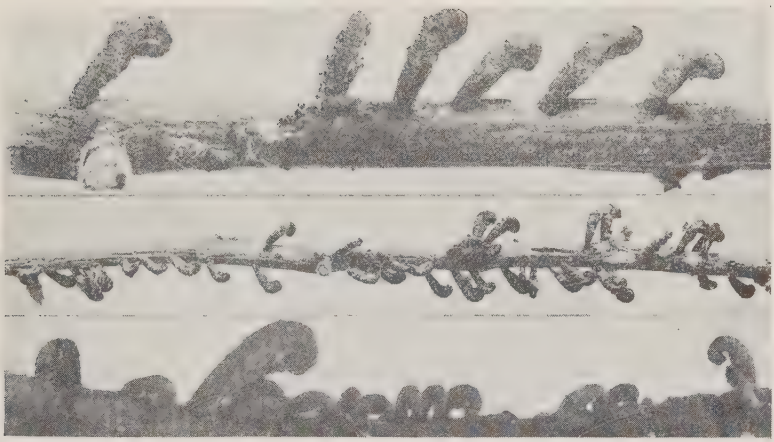
WEST VIRGINIA UNIVERSITY

Bulletin 246 December, 1931

FEB 26 1932
LIBRARY

The Pistol-Case Bearer

BY EDWIN GOULD



Various enlargements of a group of cocoons on a twig. Bottom figure: winter cocoons and fully-grown cocoon shown for comparison

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

The Pistol-Case Bearer

by EDWIN GOULD*

FOR SEVERAL YEARS the pistol-case bearer seems to have been increasingly abundant and injurious in the Ranson orchard near Charles Town, W. Va., but the attention of the Experiment Station was not called to the insect until the season of 1927, when the injury began to assume serious proportions. The insect continued to increase during the following seasons and has since become injurious in several other orchards in the vicinity as well as in orchards near Mt. Jackson, Va.

Ordinary orchard-spraying practices failed to control the insect. Even the application of extra strengths of contact insecticides and of arsenate of lead had no appreciable effect. On account of the potential economic importance of the insect to the fruit industry of the region the Experiment Station undertook a study in the spring of 1929. The results herein reported deal mostly with the work done during that season.

Fig. 1.—Typical appearance of affected tree branch

The Ranson orchard was set out in 1900. It is in excellent condition, giving good drainage for both water and air, and is on limestone soil of the Hagerstown series, which lies well. The approximate elevation is 515 feet. The orchard comprises about 85 acres and includes 4290 apple trees, the main varieties being York, Grimes, and Ben Davis. General care has been good; the pruning moderate but the spraying not of the best. Considerable dusting has been done. However, the factors which have contributed to the increase of the case bearer in the orchard are not apparent, for unsprayed trees in the neighborhood do not show any marked degree of infestation.

*These studies on life history and control were made under the direction of L. M. Peairs, entomologist of the Experiment Station.

Small numbers of the case bearer have been found also in other orchards, but evidence to date has not indicated whether the degree of parasitism is higher in lightly infested orchards than in those heavily infested.

The pistol-case bearer is a native insect which was described by Riley *(3)* in 1878 from material collected in Erie county, Pennsylvania. It has since been observed in many localities in the eastern states. A rather serious outbreak occurred in New York State in 1897. Both Lowe *(2)* and Slingerland *(4)* published accounts of the insect. It apparently subsided before doing serious damage and before control measures were thoroughly tested. No account of any important outbreak has been recorded in more recent years until the present one.

Fig. 2.—A typical apple tree in the Ranson orchard, May 28

The case bearer has been observed in orchards in various parts of West Virginia many times but has been considered more curiosity than pest. It is found from Virginia to Kansas and north to Canada.

The pistol-case bearer is a moth of the family *Coleophoridae*. The name given it by Riley was *Coleophora malivorella*. This name is still used, although the insect has also been classed in the genus *Haloptilia*. Related insects are the cherry case bearer, *C. pruniella*, and the cigar case bearer, *C. fletcherella*.

The apple is the principal host plant, but the insect will also feed upon pear, quince, and wild cherry.

The main damage is done in the spring, when the over-wintering larvae feed by eating into the leaf and blossom buds of the apple. One larva may damage several buds by its feeding, which results in ragged foliage and imperfect blossoms and sometimes in the total destruction of the buds. Feeding is continued on the leaves after they unfold and may amount to virtual defoliation of the trees or of branches. Figure 1 shows the typical appearance of a branch which

has been heavily infested. Feeding on the foliage is less important than the bud injury but may continue for a longer period. Occasional feeding on the fruit has been noted, but this seems never to be extensive.

Young larvae of the new brood feed on or in the leaves in late summer, but the damage done at this period is inconsiderable.

As stated, the main damage done by this insect occurs during its spring feeding. The extent of this damage, in an orchard as much infested as was the Ranson orchard in the two or three years before treatment, must be seen to be realized. Figure 2 intimates the conditions throughout the orchard. The branches in the upper portions of the trees had practically no foliage. Their condition suggests early spring rather than the first of June, when the photographs were made.

Obviously the destruction of so much foliage, especially during the early part of the growing season, must have a very injurious effect on the growth of the trees and on the crop for the year. If the condition recurs year after year the value of the orchard must be greatly reduced. This does not take into account the very real and serious injury to fruit resulting from the destruction of the buds in the early feeding of the insects before the leaves have unfolded.

No fruit grower can see an orchard in the condition of this one without being impressed with the fact that the pistol-case bearer is potentially an insect of the first rank as a pest. Not even the codling moth can do the damage which the case bearer, unchecked by natural enemies or by effective spraying, may inflict upon an orchard. The development of control measures is therefore of the utmost interest to all concerned with the apple-growing industry in the Eastern Panhandle.

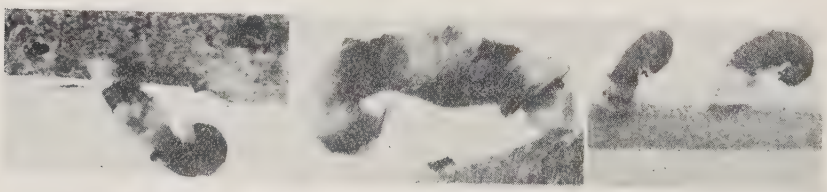


Fig. 3.—Representative views of the growth of the cocoon. Lighter areas show new portions. The pits in the bark of the left-hand figure were made in the process of attaching the cocoons

LIFE HISTORY

The pistol-case bearer passes the winter as a partly-grown larva inside its cocoon, the shape of which suggests its common name. These cocoons, attached to the twigs as shown in the figure on the cover page and in Figure 3, are about one-eighth inch in length and black in color. When the buds first show their green color the case bearers begin to feed. They detach themselves from the twigs and

move by protruding the front part of the body from the cocoon and dragging the cocoon with them to the nearest bud. Here the larva eats into the bud as far as it can reach without leaving its cocoon; it will then move to a second bud and it may injure several buds before feeding on foliage (Fig. 9). Feeding on the leaves is often slight but may be extensive, amounting to the skeletonizing of the leaves. About the last week in May the larvae reach their full growth and crawl back to the twigs, where they attach their cocoons and pupate. Before pupating they enlarge the space in their cocoons by eating into the twigs, through the bark and into the wood, so that little cavities may be found where cocoons have been removed. The larvae then reverse their positions in the cocoons and pupate.

Fig. 4.—On left, recently completed cocoon and pupa removed from it. On right, partly grown larvae removed from cocoons

It should be noted that during the spring growth the cocoon is enlarged as the insect grows, until the cocoon of the fully-grown larva in many instances is more than one-fourth inch in length. Enlargement is accomplished by adding to the open end of the cocoon, the new portions at first being white in color, and also by enlarging the diameter with material apparently built on the edges of a slit along the concave side of the cocoon. Figures 7 and 8 give some details of this process.

In 1929 the first pupa (Fig. 4) was noted on May 22, but the peak of the pupation period did not occur until June 6. As stated, the first preliminary to pupation is reversal of the larva in the cocoon. The pupae then gradually change in color from the original light yellowish brown to a dark brown. A thin pupa case is formed through which the gradual formation of the appendages can be distinctly seen. Fifteen to seventeen days are required for the transformation to the adult insect. The adults emerge through a slit formed in the construction of the cocoon as described on page 7.

The first adults were noted, in the season of 1929, on June 8, the peak of the emergence coming between the 19th and the 21st. The moths are steel-gray in color, bearing narrow, lanceolate wings with fringes of long hair on the margins. The wing expanse is about one-half inch. The moths are rather active and when disturbed will dart

about and hide on the under surface of a leaf, but seem never to fly far. They seem to fly normally at night and remain concealed in the day time. How far they may spread by natural flight has not been determined.

The sexes differ only slightly in appearance (Fig. 5). Females are larger and lighter in color than the males, having also numerous distinguishing white scales on the wings near their bases. Both sexes have legs and antennae marked by alternating rings of light and dark scales. The hind legs have two pairs of spines near their

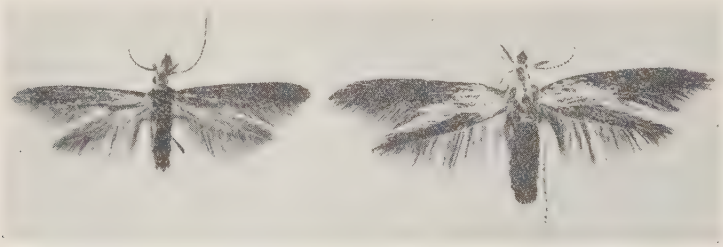


Fig. 5.—Adult moths: left, male; right, female
AFTER SLINGERLAND

distal end; the middle legs have one pair and the front legs are spineless.

The first eggs were noted on June 10 (1929). The peak of the oviposition period was between the 20th and the 23rd of June. More than 92 percent of the eggs was laid on the upper side of the leaves, as the smooth waxy surface seems to be preferred to the less smooth lower surface. In confinement the moth will oviposit on glass, wood, or other substances, but such eggs were not observed to hatch in any instance. Eggs laid by moths in cages occurred on the upper surface in 1133 cases and on the lower surface in 184 cases, showing a slightly higher percentage on the lower surface than was the case under natural conditions. Eggs are placed promiscuously over the leaves, one in a place. They are about one half millimeter in diameter, nearly as high as they are wide, and light brown or clay in color.

In spite of their small size the eggs are rather easily seen, appearing somewhat like little specks of clay scattered over the leaf. When magnified, the eggs are seen to be scalloped on the margin, with converging ridges which join an apical ring near the top of the egg. The central portion of the top is somewhat sunken and the whole suggests a minute "sample cake" baked in a scalloped pan (Fig. 6). This visible surface is, of course, only the shell or protective covering for the exposed surface of the egg and does not completely surround the egg proper, the lower surface of the egg resting directly on the leaf. The shell may therefore be lifted off the egg without apparent injury to the egg; but such eggs do not hatch. The egg proper is a gelatinous, light-brown mass. After the eggs hatch, the shells remain attached to the leaves and turn white. For

this reason they are more readily visible. Later they become detached.

The eggs hatch in from ten to twelve days. The newly-hatched larvae are brownish in color with a conspicuous dark shield on the dorsum of the prothorax and a dark spot on the dorsum of the mesothorax. The dorsal side of the metathorax is similar to that of the abdominal segments except that it becomes slightly darker as the insect grows older. Upon hatching, the insects eat their way directly into the tissue of the leaf from beneath the eggshell without being exposed. Here they feed as miners for two or three days, then emerge on the under surface of the leaf with their cocoons already formed so that they are protected to a degree. This emergence is the first indication that the eggs have hatched, for the eggs change slowly in appearance. The emergence may be at a point some distance from the location of the egg and is always on the under surface, regardless of the location of the egg.

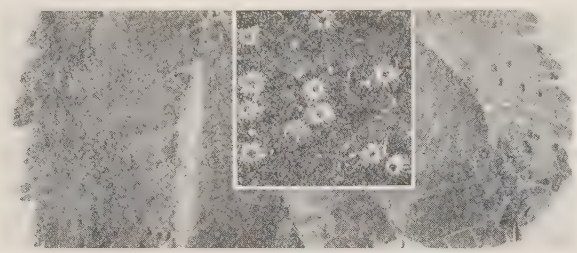


Fig. 6.—Eggs of the pistol-case bearer on apple leaf. Insert, close-up view of eggshells

The first indication of the emergence of the larva is a small spot, of lighter green color than the surrounding tissue, which is being pushed outward in the formation of the first cocoons by the larvae. The first step in this construction seems to be the chewing up of part of the leaf tissue into small granules. These are cemented together into a conical, tube-like affair, protruded from the opening in the leaf, and are enlarged to cover the entire insect as it emerges. During the process the caterpillars look as though they might have been rolled in light green dust. The cocoon is next lined with a mixture of silk and some kind of cementing material, and the leaf particles gradually turn brown and crumble off. For about one month the cases remain open along the ventral edge. The case is enlarged by building upon the anterior edge, the two edges of the ventral slit being held together during the process by a slight lining of silk, only a short portion near the posterior end being left entirely open. This serves later as the place of exit for the moth.

During the spring growth of the larva a flange-like extension is formed along the ventral margin by material pushed out through

this opening. This is shown in Figures 7 and 8. The cocoon showing the first spring addition and the slit is well shown also in Figure 8. After the caterpillars first emerge from the leaf they continue feeding until about half grown, then migrate to the twigs about September 20 to attach themselves for the winter. (See figure on cover page.) This feeding is almost entirely inside the leaf. The insects gnaw small holes through the surface, eat into the leaf as far as they can reach without leaving their cocoons, then change their location and repeat the process (Fig. 9). Whether they actually swallow the superficial tissue has not been determined. In any event it is apparent that they would get very little of any poison which might be on the surface.

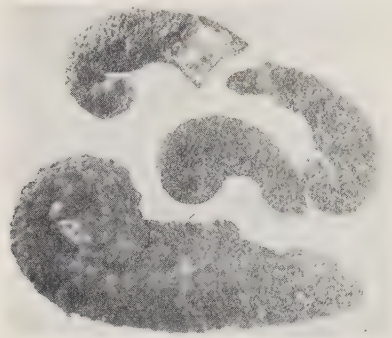


Fig. 7.—Cocoons in various stages; a larva is protruding in characteristic fashion from one. Note exit hole of parasite in middle figure

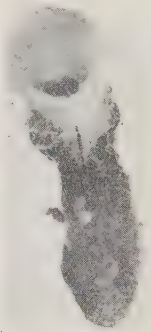


Fig. 8.—Nearly completed cocoon; the slit in the ventral surface serves later for the escape of the moth

The caterpillars normally never abandon their cases. If removed from them they may construct new ones. These resemble the cocoons of the cigar-case bearer more than the usual cases of the pistol-case bearer. The caterpillars are able to spin new cocoons up to within a few days of pupation.

When detached from the leaves or twigs they may spin silken threads by which they are suspended so that they do not drop to the ground.

Early hibernation apparently can be induced by reducing the flow of sap to the leaves.

The hibernating cocoons are firmly attached to the twigs; often part of the bark will be pulled off the twig when an attempt is made to remove the cocoon. The larvae become active in the cocoons some time before loosening their hold on the twigs to seek food. They then make their way to the nearest buds and begin feeding, continuing, as already described, until time for pupation, when they reattach themselves to the twigs, spin a silken pad or mat over the

open end of the cocoon in the cavity or depression formed in the twig, and, shortly afterward, pupate.

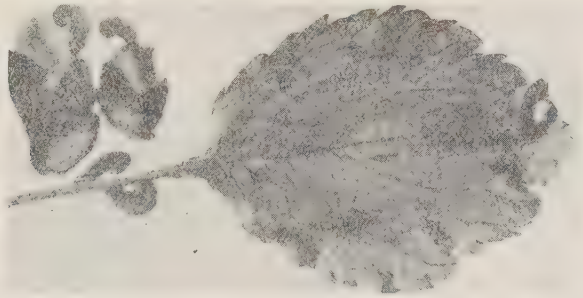


Fig. 9.—Larvae attached to petiole; others feeding on surface of leaf. Insert, case bearers feeding on buds

NATURAL CONTROL

The percentage of winter mortality, while not definitely established, seems not to be high as compared with that of many other species of insects. Some destruction of the cocoons by birds has been noted, but the importance of this has not been determined. The following species of parasites* have been reared, with percentage of parasitism and relative abundance of the different species not yet certain:

Hyposoter annulipes (Cress).
Hemiteles gracilariae (Ashm).
H. tenellus (Say)
Microbracon pygmaeus Prov.
Meteorus vulgaris Cress.
Macrocentrus sp. nov. (Muesebeck det.)
Rhoptrocentrus sp. nov. (det. Muesebeck)
Bassus coleophorae Rohw.
Monodontomerus (?) sp. nov.
Coleopisthia (Trineptis) hemerocampae Gir.
Habrocytus sp. nov. (or possibly *phycidis).*

The species last named seems to be the most important of the parasites of the pistol-case bearer. An unnamed species from this genus has been recorded from the cigar case bearer (Hammar *(1)*). Gahan expresses the opinion that the *Monodontomerus* is a secondary parasite and states that some of the others, the *Rhoptrocentrus* for example, were not ordinarily parasitic on moths. The conditions were such as to leave no doubt that all these issued from cocoons of the case bearer, since they were reared from collections of cocoons detached from the twigs.

*The parasites were identified by Mr. A. B. Gahan of the United States National Museum, Washington, D. C., or through the kindness of Mr. Gahan by Mr. R. A. Cushman of the Museum; and by Mr. C. F. W. Muesebeck.

Early suggestions assumed that the insect could be controlled by increasing the concentration of the poisons applied early in the season and by more thorough work at this time. Increased concentration of oil sprays and of nicotine in the spring sprays was also suggested. Tests of these materials failed to show a satisfactory degree of control, while observations of the habits of the insect indicated control by poisons as unlikely, since the main feeding in spring as well as in summer was inside the leaves or inside the buds, where poisons would be avoided. It seemed possible also that heavy applications of arsenate of lead in the spring might defeat their purpose inasmuch as the small insect, even when feeding on the surface of the leaf, might tend to avoid that portion on which the foreign matter occurred. Since the feeding is slow and the growth of the foliage at this period rapid, such choice would be entirely possible and might account for the failure of even six pounds of arsenate to 100 gal. of spray to give control. The contact insecticides tested in the spring were also practically useless on account of the impervious nature of the cocoon.

Failure to control in the spring together with observations on the summer development of the insect suggested that the most vulnerable period in the life of the insect might be when the larvae were newly emerged from the leaves. Since emergency treatment of the orchard under observation during the season of 1929 was necessary to prevent extensive loss the following season, it was necessary to determine quickly what material might be used for summer treatment and to apply this before the larvae had passed the stage where the treatment might be effective.

Several thousand of the insects were collected at pupation and brought into the laboratory to hasten development. As soon as the moth emerged, several caged trees were infested as heavily as possible. The young larvae thus secured were used for preliminary tests of materials. In these first dipping tests various concentrations of all the available standard insecticides were used, both stomach poisons and contact poisons. From about 40 such materials the most promising were applied in the orchard as sprays in the usual fashion. Among the materials tested may be mentioned arsenate of lead, Paris green, Bowker's green arsenate, pyrethrum extracts, neococotine, Bordeaux mixture, nicotine and penetrol, and the combination of penetrol with nicotine and other materials. Of the materials tested the best results were obtained from a combination of 1 part nicotine to 800 parts of water with penetrol at ½ percent concentration. As high as 100% kill was obtained in dipping tests with this combination. Arrangements accordingly were made to treat the orchard with this material.

All the available evidence indicated that prompt application of the spray material was desirable, as it seemed certain that, the younger the larvae were, the more susceptible they would be to the action of a contact spray. For this reason it was arranged to em-

ploy several spray outfits, volunteered from neighboring orchards. An attempt was made to select from those offered the ones which seemed most efficient, but considerable variation in effectiveness was evident.

The spray application was begun on July 17 but on account of weather conditions was not completed until the 27th. More than 67,000 gal. of material, or over 15 gal. per tree, was applied and even this quantity proved too little rather than too much.

Considerable variation was noted in the results from the different spray outfits. This probably was due in part to the outfits and in part to the operators, although every effort was made to have the work done as thoroughly as possible. The best outfit gave an average kill of 88.24%, while the poorest one showed only 75.61% kill. The two outfits showing poorest results were of the same make, indicating that the fault was with the sprayer rather than with the operators.

The average kill from all outfits, based on counts of more than 12,000 insects, was 78.92%. Kill on the outer portions of the trees was always higher than that on the inner portions and in the extreme tops. It seems probable that the percentage of kill represents the efficiency of the sprayers rather than that of the material, for kills of more than 90% were recorded on the outside of some trees, and the preliminary tests indicated an efficiency near 100% for the material under optimum conditions.

Observations in the orchard later in the season indicated that there might be some residual effect from the spraying and that the actual kill may have been even greater than the counts showed. The recovery of the orchard following the spraying was marked. New foliage developed, and the crop harvested was far above early season expectations, although far from what might have been expected had the case bearer not done its work. In the following spring there was considerable infestation, but damage did not approach in severity that of the previous season; in fact it was scarcely as pronounced as that in other orchards which had not received the special treatment but which had not shown commercial injury the year before.

The general conclusions are therefore that the 78% kill constituted a reasonably effective treatment and that this, along with the work of the natural enemies, will hold the insect in check to such an extent that commercial damage need not be feared.

The objections to the treatment developed are its expense and the fact that it involves an extra spray operation not now included in the program. Future control work will seek to discover a material which is effective when applied in the early season or along with some one of the regular sprays and which employs a material less expensive than the combination of nicotine and penetrol. For a dormant treatment it seems that a contact spray with a greater power of penetration than any now in common use will be necessary. A stomach poison to kill the larvae early in their spring feeding is a possibility but scarcely a probability, since so much injury is done

by boring into the buds, where poison can not be effective. A little later, toward the end of the feeding period, stomach poisons might well be effective if of such a nature that the insects would not avoid them and would not seek unsprayed surfaces on which to feed.

Investigations on control of the insect will continue. It seems well worth while to continue the search for better sprays until a method of control is established which shall be available at no considerable extra cost to the grower, yet enable him to prevent the accumulation of this insect in his orchard. When such treatment becomes available it should be incorporated in the spray program as a preventive treatment, so that extra treatments to prevent commercial damage will never become necessary.

For the present it may be said that a greater degree of thoroughness in the application of the sprays constituting the program now in use should tend to keep down infestation. It is known that some of the insects are killed by arsenicals during the spring feeding; if the foliage is more completely covered by more careful spraying, the percentage so killed is bound to be larger, and it is likely that in orchards where the best possible spraying is done, the insect will not increase.

SUMMARY

The pistol-case bearer is an insect which has increased in abundance during recent years to such an extent in certain orchards in the Eastern Panhandle of West Virginia that it may be said to rival the codling-moth in destructiveness. It has been found very difficult of control; so far the usual spray program, even with modifications of the materials used, has failed.

A degree of control which probably will at least prevent the increase of the insect in abundance has been secured by the use of a combination of nicotine sulphate at one part to 800 parts water with one-half percent penetrol, applied just after the hatching of the eggs in July. The utmost thoroughness in the application of this material has been shown to be necessary if a satisfactory degree of control is to be obtained.

It is recommended that special sprays to keep down the numbers of the insects be applied in orchards where it seems to be increasing, although not yet present in destructive numbers.

Further work in the development of new control methods and materials is in progress.

LITERATURE CITED

(1) Hammar, A. G.
1909. The cigar case-bearer. U. S. D. A. Bureau of Ent. Bul. 80, pt. 11.
(2) Lowe, V. H.
1897. The pistol case-bearer. N. Y. Agr. Exp. Sta. Bul. 122.
(3) Riley, C. V.
1879. The apple coleophora. Annual Report of the U. S. Department of Agriculture for the Year 1878:48.
(4) Slingerland, M. V.
1897. The pistol case-bearer in western new york. Cornell Agr. Exp. Station Bul. 124.

Bulletin 247 January 1932

1982

Pekwa — a New Soybean

BY R. J. GARBER AND M. M. HOOVER

A Field of Pekwa Soybeans Grown on the Agronomy Farm at Morgantown in Cultivated Rows, to be Harvested for Seed

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

Agricultural Experiment Station Staff

JOHN R. TURNER, Ph. D., LL. D., President of the University
F. D. FROMME, Ph. D. .....Dean and Director
GERALD JENNY, M. S., Agricultural Editor....JOHN C. JOHNSTON, Chief Clerk

AGRONOMY AND GENETICS

R. J. Garber, Ph. D.
Agronomist and Geneticist
E. P. Deatrick, Ph. D.
Associate Agronomist
W. H. Pierre, Ph. D.
Associate Agronomist
T. C. McIlvaine, Ph. D.†
Assistant Agronomist
M. M. Hoover, M. S.
Assistant Agronomist
G. G. Pohlman, Ph. D.
Assistant Agronomist
H. K. Rowley, M. S. Agr.**
Seed Analyst

ANIMAL HUSBANDRY

E. A. Livesay, D. Sc.
Animal Husbandman
C. V. Wilson, M. S.
Assistant Animal Husbandman
J. H. Longwell, M. A.
Assistant Animal Husbandman
R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman
J. H. Rietz, D. V. M. **
Associate Veterinarian

CHEMISTRY

R. B. Dustman, Ph. D.
Agricultural Chemist
Chas. E. Weakley, Jr., M. A.
Assistant Chemist
T. B. Leith, M. S.**
Assistant Chemist
I. J. Duncan, B. S.
Assistant in Agricultural Chemistry
A. H. Van Landingham, M. S.
Assistant in Agricultural Chemistry

DAIRY HUSBANDRY

H. O. Henderson, Ph. D
Dairy Husbandman
L. M. Thurston, Ph. D.
Associate Dairy Husbandman
L. F. Sutton, B. S. Agr.‡
Assistant Dairy Husbandman
G. A. Bowling, M. S.
Assistant Dairy Husbandman
R. A. Ackerman, M. S. Agr.
Assistant in Dairy Husbandry

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist
W. E. Rumsey, B. S.**
State Entomologist
Edwin Gould, B. S. Agr.
Assistant in Entomology

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist
F. D. Cornell, Jr., M. S.
Assistant Farm Mechanician
W. W. Armentrout, Ph. D.
Assistant Farm Economist
R. O. Stelzer, M. S.
Assistant in Farm Economics

HOME ECONOMICS

Rachel H. Colwell, M. A.
Home Economist
Hazel C. Cameron, M. A.
Research Specialist in Nutrition

HORTICULTURE

H. E. Knowlton, Ph. D.
Horticulturist
K. C. Westover, M. S. Agr.
Assistant Horticulturist
F. W. Craig, M. S. Agr.**
Assistant Horticulturist
Leif Verner, M. S.
Assistant Horticulturist
E. N. McCubbin, M. A.
Assistant in Horticulture
A. P. Dye, M. S. Agr.
Assistant in Horticulture
W. H. Childs, M. S.
Assistant in Horticulture

PLANT PATHOLOGY

C. R. Orton, Ph. D.
Plant Pathologist
Anthony Berg, M. S.
Associate Plant Pathologist
L. H. Leonian, Ph. D.
Associate Plant Pathologist
F. J. Schneiderhan, M. S.††
Associate Plant Pathologist
E. C. Sherwood, M. S.
Assistant Plant Pathologist

POULTRY HUSBANDRY

T. B. Clark, B. S. Agr.
Assistant in Poultry Research

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
†In charge of the Lakin Experiment Farm, Lakin, W. Va.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.
††In charge of the University Experiment Farm, Kearneysville, W. Va.

Pekwa—a New Soybean

by R. J. GARBER and M. M. HOOVER

IN 1921 a pure-line selection of soybeans which carried the nursery history number I-21-7 was grown for the first time in the rod-row trials on the Agronomy farm at Morgantown. A few years earlier, because it seemed to possess marked ability to retain its leaves, the parent plant from which this selection was derived was harvested along with many other plants from a commercial lot of the Peking variety. This characteristic has been transmitted to all its descendants; it therefore serves to distinguish them from most other varieties and selections. This new strain of soybeans has been named Pekwa* to suggest its origin.

DISTINGUISHING CHARACTERISTICS

In addition to retaining its leaves until the pods are ripe, Pekwa has several characteristics which make it desirable for forage purposes. Perhaps the best way to describe the new form is to compare it with Wilson, one of the varieties most widely grown in West Virginia.

Data in Table 1 relate to yield of seed and of air-dry hay, to height of plant, and to days to mature hay and grain for the two varieties, Pekwa and Wilson, grown under comparable conditions on the Agronomy farm for a ten-year period, 1921 to 1930, inclusive. In three of the ten years Pekwa yielded somewhat more seed, in one year the same amount of seed, and in the other six years somewhat less seed than did Wilson. The difference between the average yields of the two varieties for the ten-year period is only 0.5 of a bushel—a difference which, since not significant, may be disregarded. Somewhat similar results were obtained relative to yield of air-dry hay, except that in this case Pekwa produced slightly the greater average yield, although the difference again is too small to be of any practical significance. The tests carried out on the Agronomy farm indicate that Pekwa has about the same yielding ability, both of hay and of seed, as Wilson.

The data in Table 1 show that Pekwa is taller and slightly later in maturing than Wilson. The difference between the varieties with respect to the average heights taken just before the plants were

*The name was suggested by D. R. Dodd, formerly assistant agronomist of the West Virginia Agricultural Experiment Station. It is derived from a combination of the first syllable of "Peking", and "wa", suggesting "W. Va.", and is pronounced "Peekwa".

TABLE 1.—*Yield per acre of seed and forage, height of plant, and number of days to mature Wilson and Pekwa soybeans grown on the Agronomy farm at Morgantown from* 1921 *to* 1930, *inclusive*

Variety	Item	Year grown										Average	Difference	Odds*
		1921	1922	1923	1924	1925	1926	1927	1928	1929	1930			
Wilson	Yield of seed in bushels	31.7	22.6	29.9	25.6	23.1	28.3	17.6	32.9	25.9	16.6	25.4	0.5	2
Pekwa	Yield of seed in bushels	37.8	20.3	25.3	20.3	21.3	28.3	17.3	32.7	27.6	18.0	24.9		
Wilson	Yield of air-dry hay in tons	2.30	1.99	2.31	2.13	2.02	1.73	1.29	1.98	2.56	1.54	1.99		
Pekwa	Yield of air-dry hay in tons	2.82	2.16	2.49	2.01	2.33	1.75	1.49	2.20	1.99	1.57	2.08	0.09	5
Wilson	Height of plant in inches	38.6	42.2	52.9	43.8	41.4	34.2	33.8	45.1	36.7	30.2	39.9		
Pekwa	Height of plant in inches	43.5	42.8	57.0	48.0	44.0	36.8	35.0	47.0	39.8	33.0	42.7	2.8	8999
Wilson	Days to mature grain	121.5	125.8	138.6	132.4	130.5	146.4	134.0	136.4	132.9	127.0	132.5		
Pekwa	Days to mature grain	130.0	129.0	147.0	134.0	132.0	142.0	134.0	137.0	143.4	131.0	135.9	3.4	33
Wilson	Days to mature hay	103.5	99.0	106.0	101.0	100.0	99.0	96.0	96.9	99.0	101.0	100.1		
Pekwa	Days to mature hay	110.5	106.0	117.0	106.0	104.0	102.0	102.0	99.0	99.0	101.0	104.6	4.5	457

*Calculated according to student's method.

TABLE 2.—*Yield per acre of seed and forage of Wilson and Pekwa soybeans grown at the Lakin Experiment Farm from* 1922 *to* 1930, *inclusive*

Variety	Item	Year grown									Average	Difference	Odds
		1922	1923	1924	1925	1926	1927	1928	1929	1930			
Wilson	Yield of seed (bushels)	35.4	35.4	31.0	27.9	30.1	29.5	34.9	33.5	31.8	32.2	1.0	6
Pekwa	Yield of seed (bushels)	31.5	36.1	28.5	27.2	31.0	26.9	38.5	32.5	28.3	31.2		
Wilson	Yield of hay (tons air-dry)	2.79	2.21	2.80	2.41	2.38	2.07	3.18	2.83	2.71	2.60		
Pekwa	Yield of hay (tons air-dry)	3.06	2.42	2.67	2.52	2.51	2.22	3.33	2.92	2.66	2.70	0.1	38

cut for hay is 2.8 inches. Considerable variation was recorded with regard to number of days to mature. The variations may be attributed largely to seasonal influence. The average number of days to mature grain for Pekwa was 135.9, and for Wilson, 132.5, a difference of 3.4 days. The average number of days to mature hay for Pekwa was 104.6 days, and for Wilson, 100.1 days. The differences between the two varieties with respect to average height of plant and number of days to mature hay are real differences inherent in the varieties and cannot be attributed to chance fluctuations. The differences in number of days to mature seed for the two varieties during the several years of the tests were less consistent than the differences in number of days to mature hay. The time of cutting for hay may have been determined somewhat more definitely than the time of cutting for seed.

YIELDS AT LAKIN EXPERIMENT FARM

In Table 2 are recorded the yields of seed and of hay of Pekwa and Wilson soybeans grown under comparable conditions in varietal experiments at the Lakin Experiment farm. With respect to yield of seed, Wilson again averaged somewhat greater yields than did Pekwa, but the differences throughout the several years were not entirely consistent. A small difference in average yield of air-dry hay was obtained in favor of Pekwa, but the difference, although of some statistical significance, is very small. In general the results obtained at Lakin were similar to those obtained on the Agronomy farm at Morgantown, indicating the similar yielding ability of Pekwa and Wilson.

RETENTION OF LEAVES

In order to ascertain more accurately the relative ability of Pekwa to retain leaves as compared with Wilson, two tests were devised in 1931 on the Agronomy farm at Morgantown. Both tests were applied to plants cut at the proper stage for hay and cured in the sun until they were considered ready to store in a mow.

One test consisted of determining the "pull" necessary to detach the leaf (including petiole) from the plant. The pull was determined by placing a plant on the platform of a dial balance which permitted direct readings in grams, and weighing the downward pull necessary to detach the leaf. From four to six leaves were removed from different parts of each plant examined. A wide variation was found, but in general the plants from the Pekwa variety retained their leaves with more tenacity than did comparable plants from the Wilson variety. The results of this test are shown in Table 3. The difference between the averages is not very significant statistically, even though it is relatively great (484.8 ± 283.8).

The other test consisted of subjecting small bundles of partly-cured plants of Pekwa and Wilson soybeans to a mechanical beating

with the spokes of a wagon wheel revolved by a motor. The device is shown in Figure 1. The bundles were secured on the table, at equal distances from the axle, in such a way as to let the tops of the bundles project between the spokes of the wheel. The wheel was revolved at a fair rate of speed for a period of from 3 to 5 minutes.

TABLE 3.—*Weight in grams of "pull" necessary to detach leaves of certain field-cured plants of Pekwa and Wilson soybeans*

Variety	Frequency classes in grams																				Total	Average
	150	250	350	450	550	650	750	850	950	1050	1150	1250	1350	1450	1550	1650	1750	1850	1950	2050		
Pekwa							3	5	14	6	15	14	9	8	15	7	3	5	0	1	105	1244.8± 198.1
Wilson	1	1	8	11	8	5	21	10	7	14	10	5	2	0	1	1					105	760.0± 203.2

In some tests the Wilson bundles received the downward stroke of the spoke and the Pekwa bundle the upward stroke. In other tests the position of the varieties was reversed. In all these treatments the Pekwa variety retained a greater percentage of its leaves than did Wilson. Figures 2 and 3, respectively, show typical bundles before and after treatment. The difference in leaf retention is particularly apparent at the outer exposed surfaces of the bundles.

Figure 4 shows the difference with respect to retention of leaves at maturity between Pekwa and Wilson. When this photograph was taken the plants were ready to harvest for seed.

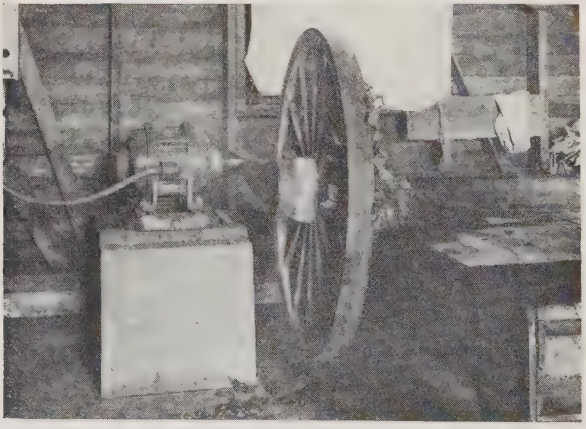


Fig. 1—Device for testing leaf retention of Wilson and Pekwa soybeans

QUALITY OF HAY

Pekwa has a finer stem, which may be inclined to vine slightly more than Wilson. The combination of fine stems and retention of leaves makes Pekwa superior to Wilson in quality of hay.

Fig. 2—Bundles of Pekwa (left) and Wilson (right) before flailing them with the spokes of a wagon wheel

Fig. 3—The same bundles shown in Figure 2, after flailing them with the spokes of a wagon wheel. Note the relative number of leaves on the bundles, particularly near the outer, exposed surfaces. Pekwa on left, Wilson on right

FLOWER AND SEED

The flower of Pekwa is purple and may easily be seen when the plants come into bloom. The seed is black and somewhat smaller than that of Wilson. As an average of several counts, Pekwa contained 295 seeds per ounce, whereas Wilson contained 244 seeds per ounce.

Fig. 4—Mature Wilson (left) and Pekwa (right) soybeans ready to harvest for seed. Note the difference in leaf retention

SUMMARY

A new variety of soybeans named Pekwa* has been developed by the West Virginia Agricultural Experiment Station. The new form originated from a single plant selected from the Peking variety. Pekwa has about the same yielding ability as Wilson, although the latter is a few days earlier in maturing. Pekwa retains its leaves longer than most varieties. This characteristic, together with its fine stems, combines to make it very desirable for hay.

---

*Another pure-line selection made from the Peking variety in 1921 has been tested rather extensively in West Virginia and to some extent elsewhere. It has been grown under the nursery history number I-21-8. This selection is very similar to Pekwa in every respect except that it usually matures a few days later and is not quite as uniform as Pekwa. A comparison of the yielding ability of these two strains may be made from data presented in W. Va. Agr. Exp. Sta. Bul. 243.

A few years ago seed of selection I-21-8 was sent to the Indiana Experiment Station to be included in varietal trials. It has proved well adapted to southern Indiana and is being increased for distribution in that state. This selection has been named Kingwa. The name is a combination of the last syllable of Peking, and "wa", suggesting "W. Va."

Bulletin 248 March, 1932

The Pathogenicity and the Variability of Fusarium Moniliforme from Corn

BY L. H. LEONIAN

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

The Pathogenicity and the Variability of Fusarium Moniliforme from Corn

by L. H. LEONIAN

THE PATHOGENICITY OF THE FUNGUS

THE WIDE distribution of *Fusarium moniliforme* Sheldon and its rôle in the ear-rots of corn are now beyond dispute; but the degree of pathogenicity of the different strains of this fungus and their proper place in the seedling-blight diseases of corn are by no means established. Conflicting opinions abound in the literature. Some investigators regard the fungus as possessing no pathogenicity whatever, while others ascribe to it certain serious consequences. Pammel, King, and Seal *(16)* reported that in 1914 some species of Fusarium attacking roots, stalks, and ears of corn caused a loss in Iowa estimated at $15,000,000.

In his earlier studies Valleau *(19)* considered *F. moniliforme* to be the most important agent in root and stalk rots of corn. Manns and Adams *(13)* reported that about twenty percent of the corn in Delaware was internally affected with *F. moniliforme*. Edgerton and Kidder *(5)*, Melchers *(15)*, and Sherbakoff *(17)* express doubt about the pathogenic nature of this fungus. Holbert *et al (7)* state that while field inoculations have failed to yield definite data concerning the ability of this fungus to cause root rot of corn, certain strains of corn are very susceptible to ear rot by *F. moniliforme*. Hoffer and Carr *(6)* proposed the theory that the so-called root rot of corn is caused by an excessive amount of aluminum in the soil. Manns and Phillips *(14)* admit that this fungus is a factor in causing root rot of corn seedlings, but find that in this respect *Gibberella saubinetii* is decidedly the more destructive.

Tehon *(18)* reports that root and stalk rots of corn are caused by *F. moniliforme* as well as by other organisms, but Branstetter *(1)*, while admitting that under greenhouse conditions this fungus can cause a certain amount of seedling blight, failed to find any case of root rot among the surviving plants. Koehler and Holbert *(9)* declare that practically every seedlot in Illinois every year is infected with *F. moniliforme*, the percentage of infection frequently being as high as 50 percent. However, they find that the fungus is not a vigorous pathogen and estimate the loss caused by it as only one percent. More recent work by Valleau *(20)*, Branstetter *(l.c.)*, and Johann, Holbert, and Dickson *(8)* indicates that a species of Pythium is the most important agent involved in corn root rots, and that *F. moniliforme* is only of secondary importance. Thus it can be seen that while there is not a unanimity of opinion, the weight of evidence seems to incline towards the theory that *F. moniliforme* is not an active root parasite and that at least in the majority of cases it is a secondary invader. Observations made and experimental data assembled by the writer favor this view.

In the summer of 1927 the entire experimental plot of Longfellow Flint corn on the Agronomy farm became heavily infested with what appeared to be a severe case of root rot. The adjoining plots, planted to other varieties, seemed to be free from it. It was soon observed that the disease was a complex one, caused by *Aplanobacter stewarti* (E.F.S.) McCulloch, and *Fusarium moniliforme*. Many of the plants were killed in the late seedling stage; those which survived were badly stunted, most of them prematurely shriveling and drying up. An abundance of bacterial slime oozed from every part of the affected plant; stem, blades, ears, corn grains, and tassels were covered with it. Cross sections of the stem showed an abundance of the characteristic yellow guttation. When these exudates were transferred to nutrient agar, colonies of *Aplanobacter stewarti* were first to form, but about two or three days later hyphae of *F. moniliforme* grew out of the bacterial colony. Tissue cultures of all parts of corn, from roots to young grains, invariably gave similar results. Presumably the bacterium was the aggressive pathogen and the fungus an intimate associate, as many subsequent inoculations failed to produce conclusive evidence that the fungus was capable of causing any destructive effect after the emergence of the corn plant from the seedling state. Nevertheless, it was deemed advisable to secure as many isolants of *F. moniliforme* as possible and to test their relative efficiency in the production of corn root rot. Accordingly, some 150 isolations were made from the roots and the basal parts of the underground stem of corn seedlings in many different localities of West Virginia. Stunted and sickly looking seedlings with discolored roots and mesocotyls were selected for isolation work. About 110 of the foregoing 150 isolations proved to be *F. moniliforme*, 20 were of *F. culmorum* type, and the remaining consisted of different genera and species of saprophytic fungi.

In the first elimination series, inoculations were made on corn growing in 250 cc. flasks, each containing 150 cc. of nutrient agar (Pfeffer's formula). The base of young seedlings near the region of the second node was wounded by a sterile needle and inoculated with bits of hyphae. Soon it became apparent that many isolants did not possess the slightest pathogenicity even under such highly favorable conditions. Therefore some 60 strains were summarily eliminated, and the remaining 50 were tested under greenhouse conditions. At 25° C. or above little or no infection occurred, all other conditions remaining favorable to the fungus. Consequently the greenhouse temperature was kept between 20 and 23°C. as much as possible. Of the 50 isolants of *F. moniliforme* which showed a certain amount of disease producing ability in the corn growing in flasks, some 30 were eliminated because they failed to attack corn seedlings under greenhouse conditions. Longfellow Flint variety was used in most of the experiments, although a number of other varieties, especially Reid's Yellow Dent, were also tried and found to be equally susceptible under favorable conditions.

Inoculation experiments were continued with the remaining organisms for three winters in the greenhouse and for two summers in the

field. From 25 to 50 plants were inoculated with each strain in the field experiments, while in the greenhouse experiments some 15 plants were used with five plants in each pot of two-gallon capacity. As soon as corn seedlings were about five inches above ground, the dirt was removed from the base of plant and the exposed region wounded with a scalpel and covered with a generous amount of rice culture in which the fungus was growing luxuriantly. The dirt was then replaced.

In the successful inoculations the first signs of the disease appeared within a week or ten days, when the lower blades wilted and dried, the entire seedling eventually becoming infected and killed. When the root tips instead of the base of the seedling were inoculated, only local lesions appeared, and in no case death or even decided stunting of the seedlings ensued. (Fig. 1.)

FIG. 1—Inoculation experiments with the different dissociants of the same isolant of *F. moniliforme*. Left to right: check, dissociants XVIII, XII, XIII, VIII, V, and II. Dissociants XVIII and XII show little or no effect upon the corn seedlings, while XIII, VIII, V, and II have stunted and killed the host. This, however, is not a constant behavior, as the reverse may occur upon the repetition of the experiment.

Positive inoculations through sound tissues were comparatively rare. Many factors may be responsible for the wounding of the corn tissues not only in the field but also in greenhouse conditions, and it is more probable to assume that ordinarily few, if any, positive infections occur through sound tissues. This assumption is particularly strengthened by the fact that when in a series of experiments the soil was sterilized, heavily inoculated with rice cultures of *F. moniliforme*, and planted to corn, no seedling diseases could be observed. Similarly, when newly germinated corn seedlings were placed in plates containing vigorously growing colonies of the fungus, kept there until nearly one

half of the roots were infected and killed, and then planted in the greenhouse or in the field, they grew into as vigorous plants as did the checks. Such a severe treatment is conclusive evidence that the fungus is only a weak pathogen, and unless given the opportunity to girdle the base of the seedlings is unable to bring about death or even stunting.

Climatic conditions greatly influence the pathogenicity of this organism. Wet, cool springs seem to be ideal. Seedlings growing in low, moist spots are particularly susceptible. If such conditions continue for very long, the seedlings may be killed by the fungus, but if warmer days follow, they recover quite rapidly. This was demonstrated in field inoculation experiments. Successive plantings at two weeks' intervals, beginning with the middle of April and extending to the middle of July, were inoculated, and the results noted. None of the inoculations made in June or July showed signs of infection, while many of those made in early May yielded diseased seedlings, some of which were soon killed, while others recovered as the temperature rose. By August they were as vigorous as the checks. Temperatures lower than 24°C. favored the fungus, while the higher ones kept the pathogen in check and aided the host plant.

THE VARIABILITY OF THE FUNGUS

EVEN THE MOST vigorous isolants of *F. moniliforme* used in the inoculation experiments were highly inconstant in their ability to bring about positive inoculations. At one time they were able to cause the seedlings to wilt within five days; at other times they were unable to bring about the slightest infection. The inoculation experiments were repeated so often and under such ideal conditions for successful infection that there can be no doubt about the recurrent nature of the pathogenicity of *F. moniliforme*. Since many of the morphological and physiological characters of this fungus are governed by an extreme plasticity, there should be no reason to suppose that pathogenicity may form an exception to the rule.

The dissociating habit of these organisms is very pronounced. Many interesting and widely differing variants have been isolated. One isolant, especially, which appeared to be the most vigorous pathogen, has been studied quite extensively. In the course of one year about 50 dissociants were segregated from a single spore culture of this strain. The more distinctive of these dissociants were used in an extensive series of inoculations in an effort to determine the effect of dissociation on pathogenicity. The results were as inconstant as the macroscopic appearance of the colonies. At one time a given dissociant showed a decided virulence, and at another time it failed to bring about any infection. Apparently there is no rule or order in the behavior of these organisms, and it seems impossible to make any kind of classification of pathogenic and non-pathogenic biotypes.

While certain macroscopic characteristics of these dissociants are fairly constant, many others are extremely fluctuative. One biotype, for instance, is a very slowly growing organism, averaging not more

than 30 mm. in a week at a temperature of 25°C., while all others grow to 80 and 90 mm. in the same length of time. While most of the time this biotype will come true, occasionally it will give rise to new sectors consisting of some one of the other dissociants, or perhaps of a new one. Similarly, the more rapidly growing dissociants may show sectors consisting of this slowly growing type. Furthermore, colorless dissociants give rise to colored ones, and vice versa; sporodochia formers produce dissociants with no ability to form such structures; those possessing aerial hyphae may give rise to some with no such hyphae, or hyphae may be formed by isolants which ordinarily have no aerial hyphae. Such an extreme variability runs the gamut of growth characters. (Fig. 2.)

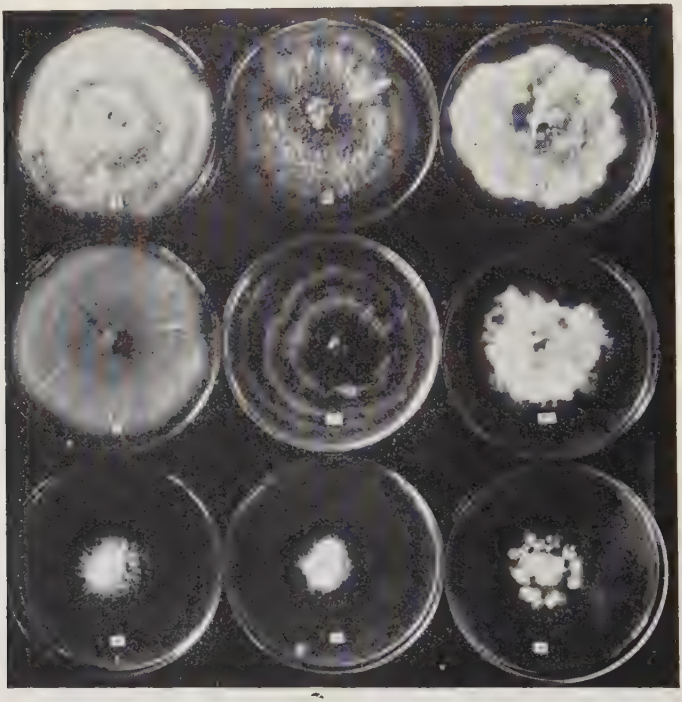


FIG. 2—Representative cultures of the 50 dissociants of a single spore isolant of *Fusarium moniliforme*, grown on the same agar and under identical conditions.

Some of the dissociants, however, fluctuate much less than others, although their stability never even approaches the immutable stage. Undoubtedly a constant selection will serve to fix certain habits, and thus the plastic nature of any given organism may be induced to conform itself to certain limits. This was accomplished with the most persistently dissociating variant, which at first would never form a pure colony, but one where two forms were found intimately associated; this, however, should not be considered a mere mechanical mixture of two organisms, but should be ascribed to a greater complexity of

protoplasm. One of these forms produced white aerial hyphae in great abundance, with the submerged hyphae colorless, or with very faint purple streaks. The other formed no aerial hyphae, and produced intensely purple submerged hyphae. The medium upon which these organisms were grown consisted of proteose peptone 5 grams, dihydrogen potassium phosphate one gram, magnesium sulphate one gram, dextrose 20 grams, and agar-agar 20 grams in 1,000 cc. of water. Transfers made from the purple sector usually gave rise to a large percentage of true-to-type colonies, although sometimes a complex colony with both colorless and colored sectors was also formed. However, transfers made from the colorless colonies failed to yield true-to-type colonies, but gave rise either to seemingly pure purple types, or to complex colonies with both the colorless and colored sectors. Test-tube cultures invariably gave rise to sectoring colonies.

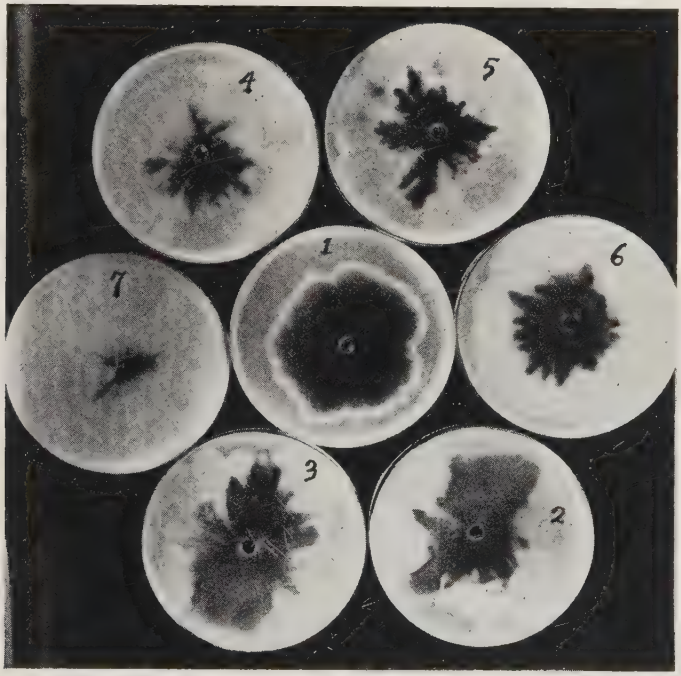


FIG. 3—Seven colonies of the same culture dissociating into purple and white variants. The holes in the center of each colony show the regions from which the inoculum discs were cut to be used in the successive transfer series shown in Fig. 4.

In order to test the potentiality of a given piece of inoculum in regard to its ability to produce the two types of cultures, the following experiment was made: seven sectoring colonies (Fig. 3), each showing purple and colorless sectors, were selected; by means of a cork borer with a bore of 5 mm., inoculum discs were cut from the purple region and transferred to seven petri dishes containing the same kind of

nutrient agar. Twenty-four hours later these inoculum discs were removed and transferred to another series of dishes. This was continued seven times, thus yielding 49 cultures, seven consecutive transfers being made in each one of the seven original cultures. As can be seen in Figure 4, only series 4, 6, and 7 showed a similarity of growth, while the remaining four series gave rise to both sectoring and seemingly pure colonies. It is interesting to note that in no case was there a pure colony of the colorless type. One would be inclined to assume that the colorless type represented the fluctuating phase, while the purple type was the more stable sort. Furthermore, it can be seen that a given piece of inoculum represents not a standardized unit, but one which may do one thing today and something else tomorrow.

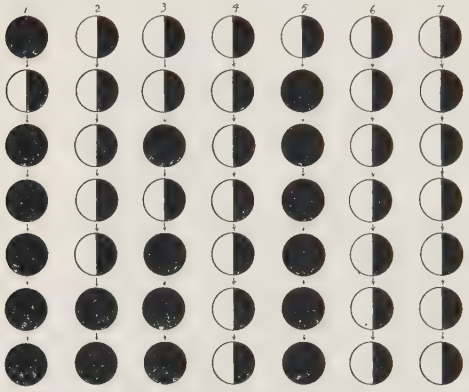


FIG. 4—Diagram showing the result of successive transfers of inoculum discs cut from the colonies illustrated in Fig. 3. The solid discs represent pure purple colonies, while black and white discs represent colonies which variously sector into purple and white variants. Note the absence of pure white colonies.

Since a piece of inoculum, no matter how small, consists of aggregates of many hyphae, and each hypha consists of a great many cells, one may be justified in assuming that the chances for the presence of different characters are greater in a piece of inoculum than they are in a single spore. A series of single spore cultures therefore was initiated. Since all strains used in this work formed no other type of spores except microconidia, cultures from single-celled units were made more reasonably certain. The orginal culture consisted of a sectoring colony; 20 single spore cultures were made from the purple sector, and fifteen from the white sector. All twenty cultures from the purple sector produced purple colonies. Then for three successive generations twenty single spore cultures were made from one of pure purple colonies, and invariably in all cases pure purple colonies were the result. In the case of the original white sector, however, two of the fifteen single spore cultures yielded pure purple colonies; successive single spore cultures for three generations gave nothing but pure purple colonies. Three of the remaining cultures showed a sectoring habit; twenty single spore cultures from the purple sector of one of these cultures yielded nothing but pure purple colonies, and in three successive generations no variation was noted in all the 60 single spore cultures made. Of the twenty single spore cultures made from the white sector, fourteen were all white, and six showed a sectoring habit.

Single spore cultures made from the white culture for two successive generations yielded nothing but white colonies. Similar cultures made from the two sectors of one of the six sectoring colonies gave rise to pure white, pure purple, and sectoring progenies. One of the ten white colonies resulting from the white sector of the original culture yielded nineteen white colonies and one sectoring colony. Single spore cultures made from one of the nineteen white colonies yielded nothing but white colonies. Cultures made from the purple sector of the one sectoring colony yielded fifteen pure purple, one pure white, and four sectoring colonies; twenty single spore cultures from one of the whites yielded only white colonies, and as many cultures made from the purple colony gave only purple colonies. The twenty single spore cultures made from the white sector of the colony yielded one sectoring colony and nineteen white colonies; twenty single spore cultures made from one of these white colonies yielded nothing but white colonies. Figure 5 represents a diagrammatical behavior of these organisms.

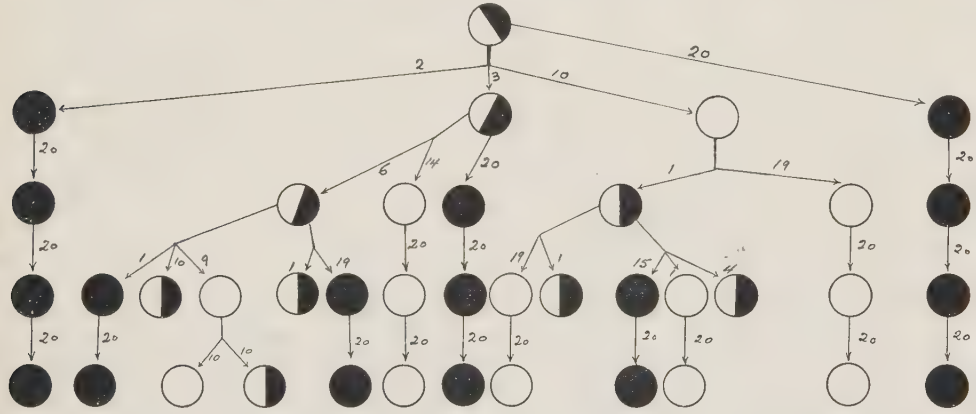


Fig. 5—Diagram illustrating the behavior of single spore cultures made from the two sectors of one of the dissociating colonies shown in Fig. 4. Arrows indicate the course of successive transfers, while Arabic numerals represent the number of single spore cultures made in each series and show the number of cultures which were pure white, pure purple, or sectoring.

Thus it can be seen that in so far as this particular instance is concerned, single spore selections tend to "purify" the line and to eliminate the constantly fluctuating habit of the original colony. However, the writer is reluctant to believe that this fixing of the type is a permanent one, as he has studied many cases where seemingly stabilized cultures suddenly and without any apparent cause resumed their former fluctuability, upsetting many nicely formulated notions. In fact, at the time of this writing, the white dissociant is already showing signs of reversion: some of the colonies are now beginning to show rays of deep purple radiating through the colorless submerged hyphae. Undoubtedly a purple sector will eventually separate itself to begin the cycle all over again. Nor is the purple dissociant constant; while it has,

as yet, shown no direct indications of reversal, it has, nevertheless, dissociated into new types and new shades of color.

Such complexity of behavior and morphology manifested by *Fusarium moniliforme*, as well as by many other fungi, is difficult to understand especially by those who instinctively cling to the belief that a given organism is rigid and immutable. These propose environmental stimuli, contamination, degeneration, hybridization, mutation, and mixochimaera as logical explanations of dissociative phenomena. No one doubts that different environmental conditions may serve to bring about striking modifications in the behavior and appearance of fungi; but when such modifications appear in the form of sectors in the same colony and under identical conditions, it becomes necessary to search elsewhere for an adequate explanation. Some workers are of the opinion that dissociations occur only on special types of rich substrata, and that the avoidance of such foods will eliminate dissociations; but the masking effect of different substrata has not been properly appreciated. An opaque substratum like oatmeal agar for instance will mask variations in the colony form; color production is masked by some agars and intensified by others; aerial hyphae, rate of growth, and almost any macroscopic character may be similarly masked or intensified. We cannot say that because a given substratum discourages color production, color has been eliminated. An organism may sector off a color-producing strain, but because of the unfavorable nature of the substratum, such a sector may escape notice; yet if accidentally transferred to a new tube of agar this new dissociant may be perpetuated, leading the worker to think that he is dealing with "new" or "abnormal" appearances and behaviors. The so-called "running out" of pure cultures is very often to be directly ascribed to such a phenomenon.

The oft-repeated and least valuable of all explanations is the one whereby contaminations and possible mixtures of strains are held to be the cause of dissociations. The periodicity of the dissociating habit, constant fluctuations back and forth within the behavior of a given single spore culture, and the tendency of mixed organisms to sector away from one another and to remain pure after once sectoring, speak convincingly against such a theory. Some believe that even a single spore culture is not necessarily pure; that a spore may have more than one nucleus, each nucleus coming from a different species, variety, or biotype. If we once allow ourselves to go thus far, then what is to prevent us from saying that even a nucleus may be a mixture of chromosomes of different specific affinities, and that a single chromosome may have a mixture of genes of diverse specific affiliations? Furthermore, when 10, 50, 100 or more dissociants can be isolated from a single spore culture, it becomes unreasonable to assume that the nuclei of so many "different" organisms can be crowded within the confines of a single spore.

Involution forms and degenerative phases abound more in bacteriological literature than in mycological writings. However, bacteriologists are coming to realize that the so-called involution forms

constitute regular and important phases in the cyclogeny of bacteria, and that such phases are just as normal as the usual text-book concept of normal cells.

Particularly in the case of organisms where sexuality does not occur, the theory of hybridization can summarily be eliminated. Even where sexuality does exist and heterothallism is a fact, hybridization and subsequent segregation of hybrid characters can still be disregarded in so far as their effect upon dissociations in pure cultures is concerned. There are too many cases showing that single spore cultures of a given strain may remain remarkably stable for months and even for years, but may eventually dissociate into new forms without ever coming in contact with other strains capable of bringing about hybridization.

The word "mutation" is no longer an explanation: mutation differs from variability merely by the degree of its intensity and permanency; it still remains to be proved experimentally that a mutant is more stable than a dissociant. We do not know why an organism mutates; neither can we explain why another organism dissociates. Therefore, by saying that dissociations are some form of mutation, we are not solving a puzzling question but are advancing another puzzle.

Perhaps the most far-fetched theory is that advanced by Brierly *(2,3)* and termed by him "mixochimaera." According to this hypothesis a somatic fusion between the hyphae of different organisms may give rise to a race possessing some new characteristics. However, it must first be demonstrated that a fusion of cell walls is a forerunner of nuclear fusion or even of a nuclear or protoplasmic migration. There is no biological basis for such an occurrence outside of sexual fusions; Brierly backs his hypothesis not with experimental data, but merely speculation. Artificially induced somatic fusions are quite common in horticultural practices where many different kinds of grafts have been made between different plants. Yet it has repeatedly been demonstrated that the understock cannot influence the hereditary makeup of the scion, and Winkler has shown that the chromosome number of each species united to form a chimaera remains absolutely unaltered.

It is true that chimaeras do occur and can be artificially induced, but there is no analogy between chimaeras and dissociants. The former do not reveal new genotypic departures; the cells of the two uniting tissues remain distinct and their hereditary potentialities remain as pure and as unaltered as if no chimaeral association had ever occurred. In the vegetative thalli of most fungi there is not even a rudimentary tissue system, and consequently chimaeras, as we know them in higher plants, cannot at all be conceived. Even if the mixing of the nuclei of different biotypes and varieties did follow as a result of somatic fusions, each nucleus would then act independently and would, eventually, either outgrow all others or be left behind. Needless to say, new biotypes could not be synthesized as a result of such nuclear mixture. Before we can even consider the hypothesis of mixochimaera, we must be able to demonstrate that two fungi, when grown together or when

mated by sexual attraction, will continue to remain closely associated in subsequent transfers and vegetative propagations. The writer *(11)* has demonstrated that such a permanent association is impossible not only in artificially mixed cultures of *Fusarium moniliforme* (Fig. 6) but also *(12)* in heterothallic strains of Phytophthora, and that the one or the other of the strains will eventually sector away and remain free of the invasion of the hyphae of the opposite sex.

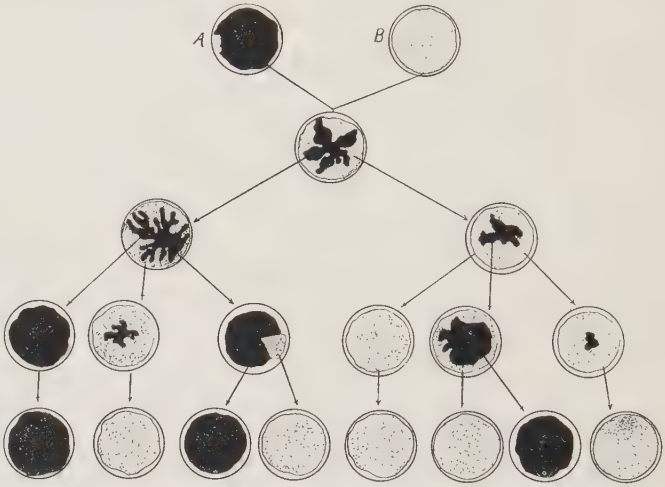


FIG. 6 — Sketch showing artificial synthesis of dissociation. *Fusarium moniliforme* biotype A (purple) and biotype B (orange) were thoroughly mixed; small bits of this mixture were transferred to nutrient agar plates. Some of the results are illustrated in this diagram: in the first generation transfer there is a complex colony consisting of an irregular purple growth surrounded with orange growth. Transfers from orange and purple sections of the colony again yielded complex colonies. In the third transfer series two pure colonies and four complex colonies resulted, while in the last transfer series all colonies were pure and subsequent transfers for several generations failed to yield any sectoring or reversing colonies. This behavior is the result of a mere mechanical mixture of the two biotypes which struggle to free themselves from one another, eventually sectoring away or outgrowing the one or the other.

Some workers have attempted to minimize the importance and the frequency of dissociations. Coons and Strong *(4)*, for instance, working with 54 species and varieties of *Fusarium* represented by 104 accessions, report diametrically opposite results to those obtained by the writer *(10)*. They state that in their hands the cultures of *Fusarium* failed to show dissociations, and that their results did not manifest any inconstancy. But apparently Coons and Strong did not become aware of the possibility of dissociation in Fusaria until the bulk of their cultural work was completed, for instead of examining their own cultures for signs of sectoring, they resorted to photographs taken earlier during their studies. Photographs are indeed poor witnesses to bring against dissociation phenomena. An examination of plates in the publication by Coons and Strong shows numerous indications of dissociations which completely escaped the notice of the authors, as can be readily seen in the following: Plate I, illustration D, the lower right colony; Plate II, illustration D, upper right and the lower two colonies; Plate III, illustration C, the lower two colonies; Plate IV, illustration F, the lower

left colony; Plate V, illustration E, the lower right colony; Plate VI, illustration B, all four colonies, illustration E, the upper two colonies, and illustration F, the upper right colony; Plate VII, illustration A, the upper two and the lower right colony; illustration B, all four colonies, and illustration C, the lower left colony.

As concerns uniformity of results which Coons and Strong claim to have obtained throughout their work, let their own illustrations speak for themselves: In Plate I, illustration E, of the four plantings one grew well, another poorly, the third showed merely a trace of growth, and the fourth failed to grow; in illustration B two grew, two failed to grow; in illustration F one grew, three failed to grow. Plate II, illustration C shows three plantings of which two grew and the third failed to grow. In Plate IV, illustration F, three plantings grew and one did not. In Plate V, illustration F, two grew and two failed to grow. The writer does not understand how Coons and Strong could state that their experiments "have not revealed such a state of inconstancy" when their own illustrations show such disconcerting behaviors.

There is a common notion that dissociants play havoc with taxonomy; on the contrary, they are of inestimable aid in bringing order out of chaos. Any genus or species which has a firm foundation is not at all affected by dissociations. Unfortunately, however, the taxonomic literature is submerged under a deluge of new genera, species, and varieties that are based on trivial, insignificant, or not readily discernible differences. It is only in such cases that dissociants help to demolish the superstructure of worthless species.

Dissociation is no more mysterious or unusual than variability; after all, an organism should contain within its protoplasm all the characteristics of the species; otherwise the theory of evolution would lose significance. Of course, it is not possible for all such specific characters to manifest themselves at one time; but the possibility is there. For instance, the potentiality for pigment production in the case of *Fusarium moniliforme* ranges through salmon, orange, red-purple, purple, lavender, blue-green, or lack of color. Therefore no one who knows this species is surprised if the different biotypes of *F. moniliforme* produce these colors. But when a sectoring colony produces one or two of these pigments, the phenomenon is regarded as mysterious. Since all these different pigments are associated with the species, and since the living protoplasm cannot acquire new characters under environmental conditions unless the potentiality for the manifestation of such characters is already present, why should not any strain of *F. moniliforme*, over a more or less extended period, manifest any or all of these colors? It is true that certain dissociants or certain isolants once obtained in pure culture may remain fairly constant in their behavior, but we have seen that a continued selection tends to fix even the most fluctuating sorts, even though the fixation and purity be comparatively relative and no more specific than the so-called impure character which has been made to submerge.

Those who are loathe to accept dissociation phenomena as fact must regard the species either as absolutely rigid and immutable, or as plastic. If the former, they must subscribe to the doctrine of special creations; if the latter, they must admit that the isolant has all the potentialities of the species even though it may be unable to express all of them at a time. Once this is accepted, then the dissociative phenomenon becomes a matter of course.

Dissociation is that phenomenon whereby a given organism traces the sphere of variability of the species. It should be regarded as a highly normal and natural behavior. Since all species are more or less variable, they should all dissociate if given the right environment. No two members of a given species are absolutely identical: if we could employ sufficiently refined tests we would probably be enabled to detect differences between any two isolants of the same variety. Dissociations serve to bring forth such differences and to enlarge our species concept.

The reason why many of us have been under the impression that dissociations yield new forms, or that certain unusual departures shown by these dissociants are new, is that we have only an imperfect or one-sided knowledge concerning the potentialities of the species. We have been in the habit of describing the species according to its morphological characters: we have usually failed to make intensive cultural studies, and have endeavored to formulate fundamental truths by superficial observations. To many of us form and size of spores and reproductive bodies constitute the sum total of the mycological concept, and the vital life processes of fungi have little taxonomic value in our scheme of classification.

Many of us, despite our professed liberalism, still cling to the notion that a species is as it appears to us at a given time. While any organisms is a unit in itself, it may, nevertheless, exhibit only one or just a few of its component phases at a time. Therefore, any genotypic strain or biotype by itself and at any one time, may not reveal the entire sphere of the species, but only a few of the units which form the specific sphere. The biotype therefore may often constitute but a fragment of a unit, only one part of a panorama; in other words, a dissociant illustrates only one phase of the species. The hypothetical composite formed by all possible dissociants should be considered the biotype, just as the hypothetical composite of all possible biotypes should be considered the species. Consequently, when a culture dissociates, it merely reveals some other character of the species, and nothing more.

Intensive cultural work with scores of dissociants has shown a remarkable continuity of specific characters, with no indication to justify the assumption that anything new has been introduced into the hereditary makeup of the species. Too long have we been chained to type species; too long have we let the mere accident of a first discovery and description shape our taxonomic concept. If instead of one, we had 100 types for each species, it would be possible for us to see that any dissociant may have its counterpart among the 100 types which form

our composite species. According to such a scheme *Fusarium moniliforme* would be recognized as nothing else but *F. moniliforme* regardless of whether it parasitizes corn or fig, banana or pineapple; whether it is a soil-inhabiting, harmless saprophyte; whether its colonies produce yellow, salmon, pink, purple, blue-green pigments, or no pigments; whether there is a profusion of aerial hyphae or no such hyphae; whether sporodochia or pseudopionnotes form or no such bodies develop; whether macroconidia are present or not; whether the fungus is a rapid or slow grower; whether the thermal death point is a little above or a little below a certain thermal death point; and whether the size and shape of macroconidia resemble the picture conveyed by the texts, or whether they vary. Despite all these variations, the monilioid microconidia, coupled with total absence of chlamydospores, form a specific continuity whereby we readily recognize *Fusarium moniliforme*. But this continuity becomes tangled once we begin to create varieties and spread thinner the already insufficient specific characters for the sake of creating new varieties or new species.

SUMMARY

Out of 150 isolations made from corn seedlings, 110 proved to be *F. moniliforme*, 20 *F. culmorum*, and the remaining consisted of various saprophytic forms.

Only 20 strains of the foregoing 110 cultures of *F. moniliforme* proved to be pathogenic to corn.

Successful inoculations were possible largely through wounds.

Seedlings wilted only when inoculated at the base of the stem just below the surface of the ground. Root inoculations yielded only localized infections.

Even when newly germinated seedlings were kept on a vigorously growing colony of the fungus in petri dishes and transplanted into the field after most of the roots were infected, they grew into normal plants.

Comparatively low temperatures (20-23°C.) were necessary for successful inoculations. No or little infection occurred at higher temperatures.

Even the most vigorous strains exhibited their pathogenicity in cycles; at one time they were able to infect the host, at another time and under identical conditions they failed to do so.

Most strains of *F. moniliforme* were extremely plastic and dissociated into many forms. One single-spore isolation produced as many as 50 variants which differed not only in their pathogenicity but also in morphological and physiological characters as well.

Single spore culture selections from the most variable types tended to fix the fluctuating types, although it is doubtful if this fixed habit becomes a permanent one.

Late planting to avoid cool, wet soil conditions seemed to be the best method to avoid seedling losses caused by this fungus.

LITERATURE CITED

1. Branstetter, B. B. corn root rot studies. Missouri Exp. Sta. Res. Bul. 113, 1927.

2. Brierly, W. B. variation in fungi and bacteria. Proc. Int. Cong. Pl. Sci. 1926, *2:* 1629-1654, 1929.

3. ———— biological races in fungi and their significance in evolution. Ann. Appl. Biol. *18:* 420-434, 1931.

4. Coons, G. H., and M. C. Strong. the diagnosis of species of fusarium by use of growth inhibiting substances in the culture medium. Mich. Exp. Sta. Tech. Bul. 115, 1931.

5. Edgerton, C. W., and A. F. Kidder. fungus infection of seed corn kernels and the importance of germination tests. La. Agr. Exp. Sta. Bul. 193, 1925.

6. Hoffer, G. N., and P. H. Carr. accumulation of aluminum and iron compounds in corn plants and its probable relation to root rot. Jour. Agr. Res. *10:* 801-823, 1923.

7. Holbert, J. R., W. L. Burlison, B. Koehler, C. M. Woodworth, and G. H. Dungan. corn root, stalk, and ear-rot diseases, and their control through seed selection and breeding. Ill. Agr. Exp. Sta. Bul. 255, 1924.

8. Johann, Helen, J. R. Holbert, and J. G. Dickson. a pythium seedling blight and root rot of dent corn. Jour. Agr. Res. *37:* 443-464, 1928.

9. Koehler, Benjamin, and J. R .Holbert. corn diseases in illinois. Ill. Agr. Exp. Sta. Bul. 354, 1930.

10. Leonian, L. H. studies on the variability and dissociations in the genus fusarium. Phytopath. *19:* 735-869, pl. XVI-XXXIII, 1929.

11. ———— attempts to induce "mixochimaera" in *Fusarium moniliforme*. Phytopath. *20:* 895-901, 1930.

12. ———— heterothallism in phytophthora. Phytopath. *21:* 941-955, 1931.

13. Manns, T. F., and J. F. Adams. parasitic fungi internal of seed corn. Jour. Agr. Res. *23:* 495-524, 1930.

14. ———— and C. E. Phillips. corn root rot studies. Jour. Agr. Res. *27:* 957-964, 1924.

15. Melchers, L. E. diseases of plants. Kan. Sta. Bien. Rpt. 69-75, 1923-24.

16. Pammel, L. H., C. M. King, and J. L. Seal. studies on a fusarium disease of corn and sorghum. Iowa Agr. Exp. Sta. Res. Bul. 33, 1916.

17. Sherbakoff, C. D. common molds of corn seed in relation to yield. Phytopath. *14:* 46, 1924.

18. Tehon, L. R. a preliminary report with the occurrence and distribution of common bacterial and fungous diseases of crop plants in illinois. Ill. Nat. Hist. Surv. Bul. *15:* 173-325, 1924.

19. Valleau, W. D. seed corn infection with *F. moniliforme*, and its relation to root and stalk rots. Ky. Agr. Exp. Sta. Bul. 226, 1920.

20. ———— P. E. Karraker, and E. M. Johnson. corn root rot, a soil-borne disease. Jour. Agr. Res. *33:* 453-476, 1926.

Bulletin 249 May 1932

Efficiency of Cooperative Livestock Shipping Associations in West Virginia

BY W. W. ARMENTROUT

UNIVERSITY OF ARIZONA
JUL 26 1932
LIBRARY

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

Table of Contents

PAGE

The Purpose of the Study ---- 3

I. Description of the Conditions of Production and Marketing of Livestock in West Virginia ---- 3
- Physical Factors ---- 3
- Number and Distribution of Animals ---- 4
- Size of Farms ---- 5
- Effect of the Fattening Quality of Grass on the System of Livestock Production and Marketing ---- 7
- Marketing Practices of Independent Dealers ---- 10
- The Seasonal Movement of Livestock to Market ---- 12

II. History of Cooperative Livestock Shipping Associations in West Virginia ---- 14
- Time of Organization ---- 14
- Reasons for Organizing Cooperative Shipping Associations ---- 14
- Volume of Business ---- 16

III. The Plan of Organization ---- 20
- The County Unit Plan ---- 20
- Constitution and By-Laws ---- 21
- Some Provisions of Constitution and By-Laws not Observed 23
- Relation of County Association to State Association ---- 24

IV. The Aims of the Cooperative Livestock Shipping Associations in West Virginia ---- 24

V. The Costs of Marketing Livestock Through Cooperative Livestock Shipping Associations in West Virginia ---- 26
- The Cost of Marketing Sheep and Lambs ---- 27
- The Cost of Marketing Cattle ---- 29
- The Cost of Marketing Calves ---- 30
- Marketing Costs in West Virginia Compared with Those in Other States ---- 30
- An Analysis of Transportation Costs by Associations ---- 32
- Summary on Transportation Costs ---- 43
- Terminal Market Costs ---- 44
- Home Expenses ---- 48
- The Manager ---- 52
- Methods of Prorating Expenses ---- 54
- Losses in Transit from Death and Cripples ---- 54
- Shrinkage ---- 55

VI. Independent Dealers' and Cooperative Prices Compared ---- 56
- Preliminary Considerations ---- 56
- Methods Employed in Obtaining and Comparing Prices ---- 60
- Lamb Prices ---- 62
- Cattle Prices ---- 64
- Changes in Dealer, Cooperative, and Terminal Market Price, 1928 and 1929 ---- 79

VII. Summary and Conclusions ---- 84
- Marketing Cost as a Factor in Measuring Efficiency ---- 85
- Marketing Service as a Factor in Measuring Efficiency ---- 87
- The Terminal Market Sales Price as a Factor in Measuring Efficiency ---- 89
- The Effect of Cooperative Associations on the Activities of Their Competitors as a Measure of Efficiency ---- 90

Bibliography ---- 91

*The Efficiency of Cooperative Livestock Shipping Associations in West Virginia**

by W. W. ARMENTROUT

The Purpose of the Study

THE PURPOSE of this study is to appraise the accomplishments of cooperative shipping associations in West Virginia; to examine their efficiency as livestock marketing agencies; and to locate factors of inefficiency, the elimination of which would make such associations more effective agencies for marketing livestock, not alone in West Virginia, but also in states where similar conditions are found.

Studies of cooperative livestock shipping associations have been made by experiment station workers in several states, chiefly where livestock is concentrated in large numbers. Many important principles have been established, some of which need modification for proper application under the conditions peculiar to West Virginia, a livestock deficit area. The conditions under which livestock is produced and marketed in West Virginia are quite similar to those found in a larger area of the Appalachian region. One outstanding difference between livestock production in this area and production in states where the most comprehensive studies of cooperative shipping associations have been made is that, while livestock production is among the chief agricultural enterprises of West Virginia, the number produced per farm is comparatively small. It seemed worth while, therefore, to study the accomplishments of cooperative livestock shipping associations in an area where the number of animals per farm is small, where the volume of business for an association is necessarily limited, and where the marketing is highly seasonal.

I. Description of the Conditions of Production and Marketing of Livestock in West Virginia

A knowledge of the conditions of production and marketing of livestock in West Virginia is essential to a proper appraisal of the accomplishments and for an understanding of the problems of her cooperative shipping associations.

PHYSICAL FACTORS

As a whole the state is hilly. The topography of West Virginia varies from small areas of level flood plains to larger areas of rugged mountains. It is mountainous in the eastern part, with level to roll-

*Presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy at the University of Minnesota.

ing land along many of the streams and on the tops of the hills and mountains. In general the valleys are narrow. Much of the hillside land is too steep for cultivation, but large areas are admirably adapted to pasture. Splendid grazing areas are found in the southeastern and northcentral parts of the state, where native bluegrass grows abundantly on the limestone and shale soils. The soils of the south-central region are somewhat less fertile, but the rough hills are also well adapted to grazing. The low sandy soils along the Ohio and Kanawha Rivers and the fertile soils of the eastern panhandle form good grain regions.

NUMBER AND DISTRIBUTION OF ANIMALS

One of the principal agricultural resources of the state is grass. Since the early settlement of the state, beef cattle and sheep have been the chief means of converting grass into human food. The hay crop alone comprises approximately 26 percent of the total crop value. While there are no extremely large producers of livestock, there are numbers of farms which graze from 20 to 50 head of mature cattle and from 50 to 75 head of sheep. On the typical farm, however, the number of animals is much smaller. The value of the beef and mutton produced in the state comprises about 12 percent of the total gross agricultural income.

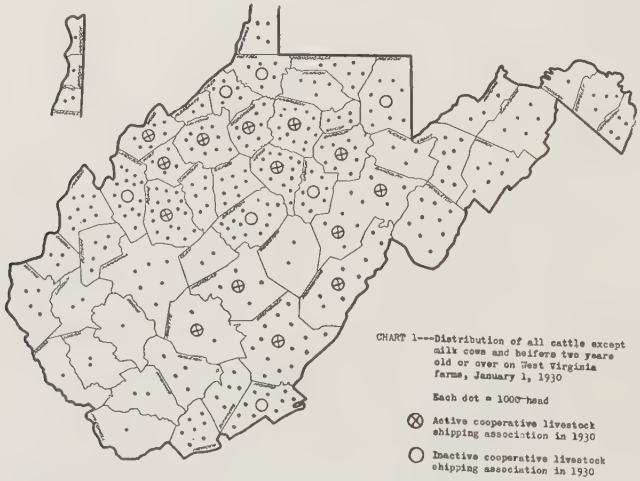


CHART 1---Distribution of all cattle except milk cows and heifers two years old or over on West Virginia farms, January 1, 1930
Each dot = 1000 head
Active cooperative livestock shipping association in 1930
Inactive cooperative livestock shipping association in 1930

On January 1, 1930, there were 309,714 cattle other than dairy cows and heifers on farms in West Virginia.* In Chart 1 is shown the distribution of these cattle by counties. The number of cattle going to market from each county, however, is not proportionate to the distribution as shown in Chart 1 because of certain movements of cattle within the state which are explained further on.

There was a total of 531,000 of "all cattle and calves" on farms

*U. S. Department of Agriculture, Crop and Livestock Estimates. 1930.

in the state on January 1, 1930.* In Chart 2 is given their distribution by counties. Of these animals 230,000 were classed as milk cows and heifers, but many of these were of beef breeds, kept as dual purpose cows and constituting an important source of calves kept for beef production. The actual number of beef-producing animals therefore was somewhere between the number classed as "cattle other than dairy cows and heifers" and "all cattle."

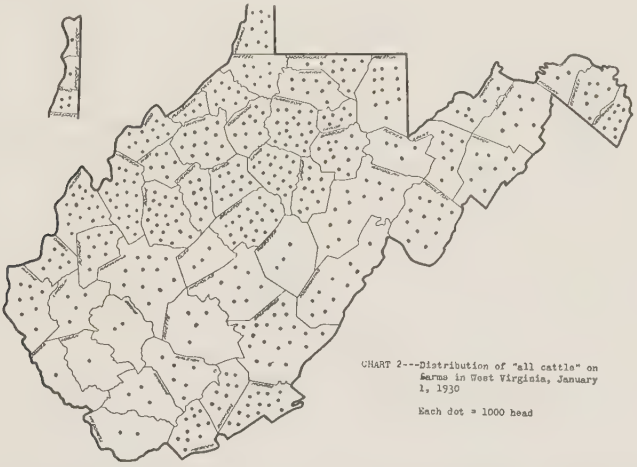


CHART 2---Distribution of "all cattle" on farms in West Virginia, January 1, 1930

Each dot = 1000 head

There were 629,000 sheep and lambs on West Virginia farms on January 1, 1930.* Their distribution by counties is shown in Chart 3. The distribution of market lambs corresponds very closely with the distribution of sheep as shown in this chart, except in a few counties in the northwestern part of the state and in the northern panhandle, where fine-wool breeds are kept.

Charts 1 and 3 indicate that the bulk of the beef cattle is concentrated in 21 of the 55 counties, and that sheep are distributed a little more generally over the state, their production constituting a major enterprise in some 27 counties. With the exception of the areas in which fine-wool sheep are produced, the counties having the larger number of beef cattle usually are the ones having the larger number of sheep. A combination of sheep and beef cattle is the most typical livestock enterprise in the state.†

SIZE OF FARMS

A statistical picture of farms by counties as reported by the United States Census of Agriculture for 1925 is shown in Table 1.

The following facts are adapted from data in Table 1: the average West Virginia farm is small in size; the ratio of pasture land to crop land is high; a larger percentage of the farms reported beef cattle

*U. S. Department of Agriculture, Crop and Livestock Estimates, 1930.

†The hogs produced in the state are grown largely for home consumption. Few shipments are made to outside markets; for that reason a consideration of the marketing of hogs is omitted from this study.

TABLE 1—*Number and size of farms by counties, percentage reporting beef cattle and sheep, and average number of such animals on farms so reporting, 1925*[1]

County	Number of farms	Average number of acres per farm	Average acreage of crop land per farm	Average acreage of pasture land per farm	Percentage of farms reporting beef cattle	Number of beef cows[2] per farm	Percentage of farms reporting sheep	Number of ewes per farm[3]
Barbour	1935	90.1	19.0	58.9	63	2.9	16	14.5
Berkeley	1436	107.6	54.0	28.5	20	2.9	11	23.4
Boone	1066	68.0	17.3	18.6	64	1.4	3	7.6
Braxton	2617	101.5	16.5	48.5	78	2.8	26	16.7
Brooke	364	115.8	43.3	50.7	15	0.8	19	57.1
Cabell	2274	64.6	18.9	25.7	51	1.6	1	13.0
Calhoun	1594	99.2	19.0	48.9	79	2.2	8	14.0
Clay	1159	68.3	16.5	22.4	77	2.1	8	11.5
Doddridge	1165	115.0	16.3	72.3	85	3.0	29	20.1
Fayette	1725	50.5	17.3	18.2	38	1.1	11	8.5
Gilmer	1544	125.0	19.6	62.6	84	3.5	22	18.7
Grant	945	215.0	27.5	114.2	86	4.1	52	20.7
Greenbrier	2682	118.7	21.0	63.7	72	2.7	37	21.5
Hampshire	1766	179.3	34.3	58.9	63	2.5	29	16.0
Hancock	360	101.2	37.1	47.2	6	7.9	8	28.3
Hardy	1266	184.3	25.3	70.9	58	2.7	49	16.4
Harrison	2108	84.1	16.7	55.7	62	2.7	15	21.5
Jackson	2701	100.0	22.2	64.1	71	2.6	15	18.2
Jefferson	920	119.8	68.5	38.3	29	1.8	24	33.4
Kanawha	3691	57.7	15.7	26.8	17	2.1	1	21.5
Lewis	1729	128.1	18.2	85.6	81	3.6	41	21.9
Lincoln	2298	78.8	21.2	21.6	21	0.7	3	5.0
Logan	753	74.5	13.0	13.0	74	1.7	3	6.3
McDowell	1418	38.3	10.9	6.5	24	1.8	8	4.0
Marion	2460	65.1	11.6	40.4	21	1.3	10	21.2
Marshall	1681	102.4	30.4	53.3	17	1.3	35	38.1
Mason	2455	100.2	26.5	56.3	47	3.1	8	16.8
Mercer	2310	76.8	15.1	34.9	45	1.6	14	16.5
Mineral	758	193.3	32.2	72.6	39	3.7	24	21.7
Mingo	1140	65.7	12.6	11.2	25	0.1	9	6.8
Monongalia	1835	82.6	19.2	49.2	57	1.9	19	29.0
Monroe	1961	121.1	22.4	54.0	84	2.7	41	20.8
Morgan	842	119.3	37.7	25.1	66	2.0	1	11.2
Nicholas	1574	86.4	20.2	30.5	83	2.9	41	11.9
Ohio	460	83.6	34.2	44.7	8	2.0	15	39.1
Pendleton	1319	210.1	27.9	77.9	70	4.6	21	20.1
Pleasants	858	80.7	18.4	38.9	37	1.7	7	22.9
Pocahontas	1383	164.8	23.4	92.7	74	4.3	65	30.1
Preston	2731	86.5	22.1	46.7	59	2.8	21	12.3
Putnam	2053	87.2	24.6	37.8	49	1.7	3	13.1
Raleigh	1708	71.5	16.1	27.0	59	1.9	12	9.4
Randolph	1717	164.5	22.8	100.4	68	3.6	29	23.8
Ritchie	1503	108.9	21.2	59.3	62	1.9	24	19.2
Roane	2514	113.6	20.1	70.9	84	3.3	16	18.5
Summers	1921	97.2	17.7	42.6	79	2.4	23	12.4
Taylor	1055	73.9	15.0	45.9	29	0.1	11	16.8
Tucker	763	137.7	21.3	57.3	40	2.9	25	16.8
Tyler	1211	104.3	20.5	64.6	44	1.3	17	28.6
Upshur	2149	80.3	14.8	45.3	68	2.5	25	11.7
Wayne	2883	77.3	16.9	31.1	36	1.5	2	4.6
Webster	1065	103.9	14.1	25.1	68	2.1	35	12.8
Wetzel	1710	91.3	23.7	42.1	50	1.9	18	27.2
Wirt	1166	100.6	22.4	50.2	49	3.4	12	19.0
Wood	2422	76.6	19.5	43.7	47	3.5	6	20.7
Wyoming	1257	85.0	17.9	31.3	38	1.4	18	6.1

[1]United States Census of Agriculture, 1925, Part II, U. S. Department of Commerce, Bureau of The Census.
[2]Number of farms reporting beef cattle used as base.
[3]Number of farms reporting sheep used as base.

than sheep; the average number of beef cows per farm is small, while the average flock of ewes is of fair size. The bulk of the livestock production is on small-sized farms and from small herds and fair-sized flocks. Thirty-six percent of the farms in the state in 1925 comprised fewer than 50 acres, 65 percent fewer than 100 acres, and 86 percent fewer than 175 acres. Only three counties averaged more than four beef cows per farm, while only one county, with the exception of those producing fine-wool breeds, averaged more than 30 ewes per farm. There are few carlot producers in the state. The patronage of shipping associations is therefore limited to small producers.

A large majority of the cattle move to market as mature, grass-fat cattle. A few move to neighboring states and to eastern markets as feeder cattle, but most of the feeder stock is absorbed within the state. Practically all of the lambs move to market as grass-fat lambs —the large majority to out-of-state markets.

EFFECT OF THE FATTENING QUALITY OF GRASS ON THE SYSTEM OF LIVESTOCK PRODUCTION AND MARKETING

The nature and productivity of the soil, and in a smaller way topography and altitude, have played leading roles in the development of the systems of livestock production and marketing in the state. The fattening quality of the grass is determined largely by the nature and productivity of the soil. In turn, the fattening quality of the grass has a direct bearing on the systems of production and marketing which are being practiced.

Sections of the state in which the bulk of the livestock is produced may be divided into three general types. Those sections in which the grass is of such quality that mature beef steers may be finished on grass alone are designated in this publication as Type 1; those in which grass is an important agricultural resource, but the quantity per acre so small and the quality such that it is impossible to finish mature beef animals on grass alone, are designated as Type 3. Sections designated as Type 2 fall between these extremes and may, and for the most part do, contain some areas similar to those found in both the Type 1 and Type 3 sections. It is characteristic of the sections designated as Type 2 to have a good quantity of grass per unit of area, but of such a quality that mature animals will not fatten on it.

Without designating all counties which would fall in each type, it seems sufficient to point out that Greenbrier, Monroe, Harrison, Lewis, Barbour, and Jackson counties have large areas classed as Type 1; Nicholas, Webster, Braxton, Clay, and Randolph counties, large areas classed as Type 3; and Doddridge, Gilmer, Calhoun, and Roane counties, large areas classed as Type 2.

If we assume that the counties named are representative of the three types in which they have been placed, it is possible to present a

TABLE 2.—*Average number of acres of crop land and pasture land, number of beef animals[1] and ewes per farm on farms reporting such, and percent each item is of Type 3, by type of region, 1925[2]*

Type of area	Crop land per farm		Pasture land per farm		Beef cows per farm		Calves under 1 yr. old per farm		Heifers 1 yr. and under 2 yrs. old per farm		Steers 1 yr. old and over per farm		Steers and heifers per farm		Ewes per farm	
	Average number acres	Percent of Type 3	Average number acres	Percent of Type 3	Average number	Percent of Type 3	Average number	Percent of Type 3	Average number	Percent of Type 3	Average number	Percent of Type 3	Average number	Percent of Type 3	Average number	Percent of Type 3
Type 1	20	110	63	126	3.0	107	2.2	110	1.2	120	3.7	195	4.9	169	21	130
Type 2	19	105	60	120	3.0	107	2.1	105	1.2	120	2.6	137	3.8	131	18	112
Type 3	18	100	50	100	2.8	100	2.0	100	1.0	100	1.9	100	2.9	100	16	100

[1]Number of farms reporting beef cattle used as a base. [2]Adapted from United States Census of Agriculture, 1925, Part II.

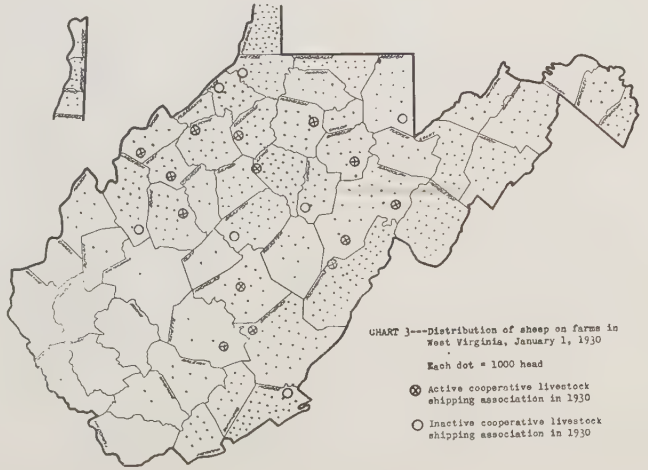
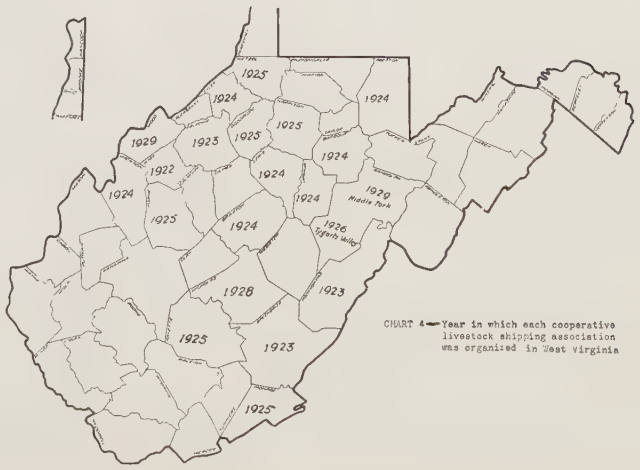


CHART 3---Distribution of sheep on farms in West Virginia, January 1, 1930
Each dot = 1000 head
Active cooperative livestock shipping association in 1930
Inactive cooperative livestock shipping association in 1930



statistical picture of each type of section. From data in the United States Agricultural Census for 1925 it is found that 34 percent of all (12,000) farms in those counties placed in the Type 1 section contained fewer than 50 acres, 63 percent contained fewer than 100 acres, and 84 percent fewer than 175 acres. In the counties comprising sections designated as Type 2, however, only 26 percent of the farms contained fewer than 50 acres, 59 percent fewer than 100 acres, and 83 percent fewer than 175 acres; but in sections designated as Type 3, 35 percent of the farms contained fewer than 50 acres, 66 percent fewer than 100 acres, and 86 percent fewer than 175 acres. There is little variation in the percentage of the different-sized farms in Types 1 and 3, but in counties of Type 2 a smaller percentage of farms was under 50 acres.

In Table 2 the acres of crop land and pasture land and the number of various kinds of livestock per farm are shown for these counties, classified by type of section.

Large numbers of the farms in Type 3 sections are situated on very poor soils. Even the farms on the better lands do not have enough crop land to produce sufficient winter feed for as many mature cattle as their pasture would carry in the summer. Most of the small farms produce hay sufficient for their milk cows alone, and must dispose of the calves when the pasture is gone. Consequently from the smaller and poorer farms calves are sold either as vealers or to a dealer or neighbor who is in a better position to winter them. As yearlings they may be found on the better farms, where they are carried through their second summer and perhaps their second winter. As two-year-olds, however, they are most likely found on farms of the sections designated as Type 2, where they are wintered and pastured the next summer. They then go on to farms in Type 1 sections, where they are finished on grass as three- or four-year-olds.

It is customary for most farms in Type 1 sections to winter only a part of the cattle which are pastured the next summer. It may be seen from a map of the state that counties falling in each type of section are somewhat scattered over the state; a county of one type may adjoin a county of another type. As a result the distance for moving the cattle is not great.

An analysis of the data on farms and livestock in West Virginia as found in the United States Census of Agriculture for 1925 bears out this description of the movement. Table 2, formed by combining data for those counties placed in designated types, shows that the average farm in Type 1 sections had one acre more of crop land and three acres more of pasture than the average farm in Type 2; and that the average farm in Type 2 had one acre more of crop land and ten acres more of pasture than the average farm in Type 3.

Farms in the Type 1 area carried more beef animals* per acre of crop and pasture land than those in Types 2 and 3, and farms in

*To arrive at an average number of beef cows, calves, heifers, and steers on farms, the number of farms reporting beef animals was used as the base.

the Type 2 carried more than those in the Type 3 area. It may be observed from Table 2 that while farms in the Type 3 area were carrying slightly more cows, calves, and heifers per acre than those in the other areas, with only 26 percent more pasture land, farms in the Type 1 area carried 95 percent more steers, and farms in the Type 2 area with 20 percent more pasture land carried 37 percent more steers than those of the Type 3. From these data it appears reasonable to suppose that the older beef animals moved on to the better grazing lands. No data are available concerning the number of animals which came in from other states, but the number was known to be small. The majority of the larger numbers per farm in Type 1 above Type 2 came from sections of Types 2 and 3, and the larger numbers per farm in sections of Type 2 above Type 3 came mainly from sections of Type 3. Of course there are many variations from this, but the movements described are fairly typical for a large percentage of the cattle produced in the state.

MARKETING PRACTICES OF INDEPENDENT DEALERS

With such a system of production it is not surprising to find that many farmers become "cattle traders" either as a side line or as their chief activity. Purchases and sales are greatly out of proportion to the number of cattle produced. Large numbers of beef cattle change farm and owner each year from the time they are calves until they start for market. The independent dealer thrives under such conditions. Not all ship to market, many confining their activities to buying from one farmer and selling to another who desires additional cattle for wintering or pasturing. Some dealers specialize in a particular type of cattle while others purchase any sort that is offered for sale. The cooperative shipping associations have not entered this field of local marketing except in a very minor way and, therefore, offer no service to the farmer who wishes to sell or buy immature cattle. This field of marketing is left almost wholly to the independent dealer and comprises a large part of the trading in cattle within the state.

Systems of buying and selling livestock on contract which have come into common use in West Virginia further limit the volume of business available for the shipping associations. Contract buying and selling in the state takes many forms, but the most prevalent systems are the following: first, a private buyer who owns cattle sells them to a farmer for a stipulated price, agreeing to re-purchase them later at a designated time, at a price higher by from 75 cents to $2 per hundredweight than the price at which the farmer bought them. The farmer may either winter or pasture the cattle, or he may keep them for a full year. The amount of the increase in price at which the cattle are re-purchased depends on several factors which need not be enumerated here. By this method the farmer owns the cattle, pays taxes on them, and runs the usual risks which go with ownership. His profit depends on the weight he can put on them

and the cost by which this is accomplished. But, he has a guaranteed price, provided the dealer with whom he contracted has sufficient funds to "take up" the cattle at the designated time.

A second practice which is in common use is for the dealer who owns cattle to "let them out" to farmers for wintering or pasturing for a specified sum per head, or per pound increase in weight. Under this system the private dealer assumes all the risk of ownership, while the farmer has a guarantee of his returns.

A third practice is for dealers to "contract" with the producer for the purchase of cattle several months in advance of the time of delivery. The "contract" is ordinarily nothing more than a verbal agreement. It is not unusual for the contract to be made a year ahead of the time of delivery, but more often it is made in the late winter or early spring for fall delivery. It is the usual practice to contract for lambs during March and April for delivery in August and September. The earliness of contracting and the aggressiveness of the dealers in closing contracts depend largely on their opinions of the prospective price trends. If the dealer expects a rising price trend he contracts early and is aggressive in his competition, but if he expects a falling price trend he will wait as long as possible to make contracts or possibly refuse to make them at all.

The buyer usually inspects the cattle for which he contracts, agreeing to pay a specified price at the date of delivery. In contracting for lambs, however, the buyer often does not see them when the contract is made but agrees to take all of a certain weight at a specified price. They are usually bought on the basis of two weight classifications—those weighing 60 pounds and above, and those weighing below 60 pounds. The weight classification varies somewhat with the prospective market demand and price for lambs. The seller is bound by his contract as is also, theoretically, the purchaser, but there has been considerable difficulty in the state with unreliable dealers who break contracts on a declining livestock market.

A fourth method used by the independent dealer to assure volume is to loan small sums of money as advance payments on livestock which the farmers will want to sell a few months later. Seldom does the dealer take a chattel mortgage or note, but there is an understanding that he is to buy the livestock. This method is most commonly used in the purchase of young cattle and lambs. It enables the dealer to have control over the disposal of the livestock without investing large sums of money in them or being bound by contract to purchase them at a stipulated price.

In a system of production and marketing livestock such as found in West Virginia, five factors appear to be important in their effect on the activities of cooperative livestock shipping associations. First, independent dealers are largely speculators in livestock. The speculation may extend over a period of two to three years when a calf or yearling is bought and title is held until it is a mature animal. Second, there is a large amount of local purchasing and selling in which the cooperative association takes no part. Third, the avail-

able vo'ume for cooperative associations is limited by the relatively small production in each county. Fourth, a large portion of the livestock in the state is controlled by the independent dealers, either through ownership, contract, or otherwise, thus further limiting the volume which is available to cooperative shipping associations. Fifth, during years of a falling market, many farmers resort to the cooperative shipping association to market their livestock when private dealers break their contracts or show little interest in buying. The effects which these factors have on cooperative shipping are shown further on.

THE SEASONAL MOVEMENT OF LIVESTOCK TO MARKET

The movement of livestock to market is highly seasonal. In 1929 approximately 50 percent of the cattle and 75 percent of the lambs were moved to market during August, September, and October. The number of carloads of cattle and calves moving from West Virginia in 1929, tabulated by counties in which the shipping points were located, is shown in Table 3, the data for which were obtained from "station freight records" in the offices of the Baltimore and Ohio Railroad in Baltimore, Maryland; the Chesapeake and Ohio Railway in Richmond, Virginia; and the Norfolk and Western Railway in Roanoke, Virginia. The data as presented are accurate for the territories served by these railroads, except that they do not include shipments by truck, or animals driven into adjoining states. While records of the number of animals trucked to market are not readily available, it is known that the number thus transported in 1929 was small.

There are a few other railroads traversing small areas of the state from which it was not practicable to obtain records of shipments. It is estimated that by adding the number shipped over these railroads and those by truck, to the number shown in Table 3, the total for the state would be increased by not more than 15 percent. This, however, would not change materially the picture of the seasonal movement from that shown in Table 3. If 15 percent be added to the total shown it would make 2,359 as the total number of carloads of cattle and calves going from West Virginia to out-of-state markets in 1929. It was not possible to ascertain the number of cattle and calves separately because the records preserved by the railroads listed cattle and calves together. The largest movement in any month of 1929 was in September; however, some counties shipped more during August and some more during October than in September. In respect to seasonal movement, the movements to market during 1929 were fairly normal.

The number of carloads of cattle and calves **shipped** from each county as shown in Table 3 does not necessarily correspond with the number of carloads of such animals **marketed** from each county. The table shows the carloads summarized by counties in which the shipping points were situated. A station situated near a county line

often draws shipments from other counties. An estimate of the maximum volume available to a county shipping association, however, may be arrived at from such a tabulation.

TABLE 3—*Number of carloads of cattle and calves loaded at shipping points within counties specified, by months, 1929*

County	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Barbour	1	..	..	..	..	2	5	45	13	15	10	4	95
Berkeley	..	..	..	..	1	..	..	1	..	1	..	..	3
Braxton	..	..	..	..	..	7	8	31	24	18	9	..	97
Cabell	..	..	..	..	3	6	10	6	7	5	..	..	37
Clay	..	..	..	..	..	..	..	3	4	7	2	..	16
Doddridge	1	..	..	1	1	1	6	7	11	8	13	4	53
Greenbrier	..	..	1	2	4	9	8	65	52	24	8	1	174
Hardy	4	3	4	1	..	1	..	36	7	2	1	10	69
Hampshire	..	2	1	..	..	..	1	4	..	..	3	1	12
Harrison	..	1	..	1	1	1	11	69	75	38	44	5	246
Jackson	3	1	..	..	5	9	11	29	56	47	13	2	176
Grant	..	1	2	4	1	..	4	6	7	2	3	1	31
Jefferson	..	..	..	1	1	..	10	..	..	..	..	3	81*
Lewis	1	..	..	1	..	1	17	21	45	25	24	4	139
Lincoln	..	..	..	..	..	..	..	..	..	1	..	..	1
McDowell	..	..	..	..	..	..	..	1	..	..	..	..	1
Marion	..	..	2	..	..	3	3	3	8	5	2	3	29
Marshall	2	..	..	..	..	2	6	5	3	2	4	1	25
Mason	2	..	..	7	3	3	7	20	11	10	6	5	74
Mercer	..	..	..	..	..	..	..	..	..	..	..	..	31*
Mineral	..	..	..	..	..	..	..	1	..	1	..	..	2
Monongalia	..	..	..	..	..	..	3	5	3	1	2	2	16
Nicholas	..	..	..	5	1	..	..	..	..	2	..	..	8
Ohio	..	..	..	..	..	..	..	3	..	..	..	..	3
Pocahontas	..	..	1	..	..	..	2	22	43	25	4	..	97
Preston	2	..	3	8	6	2	7	6	5	12	5	2	58
Putnam	..	..	..	..	..	..	..	..	..	1	..	1	2
Monroe	..	..	..	..	..	1	2	11	15	8	1	..	38
Randolph	..	..	..	..	..	..	..	..	1	..	1	..	2
Ritchie	..	..	..	..	..	2	3	15	19	21	8	1	69
Roane	..	..	..	..	..	..	3	14	44	56	5	2	124
Summers	..	..	..	..	..	..	2	9	6	2	2	1	22
Taylor	..	..	..	..	..	..	2	9	7	9	14	2	43
Tyler	..	..	..	..	..	..	..	..	3	2	1	..	6
Upshur	..	..	..	..	..	..	..	10	10	7	..	..	27
Wayne	..	..	..	..	..	3	6	7	4	..	..	..	20
Webster	..	..	..	..	1	..	1	..	1	1	..	..	4
Wetzel	..	1	..	1	3	2	6	5	5	5	7	4	39
Wirt	..	..	..	..	1	4	6	10	3	7	2	..	33
Wood	..	..	..	..	1	4	6	10	11	14	1	2	49
Total	16	9	14	32	33	63	156	489	503	384	195	61	2052*

*Complete record by months not available.

The number of single and double decks of sheep and lambs moving to out-of-state markets in 1929, classified by months and by counties in which the shipping points were situated, is given in Table 4. The data were obtained in the same manner and from the same sources as were the data of shipments of cattle and calves. The same limitations therefore apply to these data as have been indicated with reference to cattle and calves. If 15 percent, the estimated deficiency in the data, be added to the totals shown in Table 4, the number of decks of sheep and lambs marketed from the state in 1929 would be 982 single decks and 597 double decks.

Approximately 75 percent of the sheep and lambs were marketed in August, September, and October. Counties situated in the central portion of the state marketed the majority of their lambs in August,

and those in the eastern part in September, with the exception of Pocahontas county, which supplied the bulk of the October shipments.

From Tables 3 and 4, two factors having an important effect on cooperative livestock shipping associations in West Virginia may be pointed out. The maximum volume possible for them to obtain is small, and the movement to market is highly seasonal. The manner in which these factors affect the quality of management and the efficiency of the cooperative associations is pointed out further on.

II. History of Cooperative Livestock Shipping Associations in West Virginia

TIME OF ORGANIZATION

The first cooperative livestock shipping association in West Virginia was organized in Wirt County in 1922, an outgrowth of a local lamb pool which had been operated for several years by farmers in the county. During 1923, associations were organized in Pocahontas, Greenbrier, and Ritchie counties, and in 1924 in Braxton, Lewis, Barbour, Preston, Jackson, and Tyler counties. It was also in 1924 that the county associations federated into a state association, the West Virginia Cooperative Livestock Shipping Association, Inc. During 1925 organizations were effected in Monroe, Fayette, Roane, Wetzel, Harrison, and Doddridge counties, and during 1926 in Randolph county. In 1929 an association was started in Wood county and the second one in Randolph county.

By 1929 twenty-one associations had been organized in the more important livestock producing counties of the state. Charts 1 and 3, which give the number of beef cattle and sheep, respectively, by counties, show also the location of the active and inactive associations. It may be seen that few important livestock counties remain in which a cooperative shipping association has not been formed.

The year in which each county association was organized is shown in Chart 4 (page 8).

REASONS FOR ORGANIZING COOPERATIVE SHIPPING ASSOCIATIONS

Two principal reasons may be given for the organization of cooperative shipping associations in West Virginia: first, belief on the part of farmers that independent dealers were taking excessive margins; second, the activity of the Farm Bureau and of the University Agricultural Extension Division in promoting cooperatives. Unfortunately, records of margins which dealers obtained before the organization of cooperative associations in the state are not available. They were reported to have taken margins of as much as $3 per cwt. on lambs and $1.50 to $2 on cattle. Such margins were thought to be excessive. In most counties there were several independent dealers who bought livestock. This should have provided sufficient competition to have narrowed the margins, but all seemed

to pay about the same prices and take about the same margins. If there was no conscious effort on their part to stifle competition, the result was the same since most of the smaller dealers followed the prices paid by the large dealer in the community.

TABLE 4—*Number of carloads of sheep and lambs loaded at shipping points within counties specified, by single or double deck, by months,† 1929*

County	Jan.		Feb.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.		Total	
	S[1]	D[2]	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D
Barbour	..	..	..	..	..	..	..	..	1	..	2	3	12	6	1	..	..	..	..	..	16	9
Berkeley	..	..	..	..	..	..	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	3
Braxton	..	..	..	..	..	..	1	..	7	8	12	21	3	14	3	..	..	..	..	..	26	43
Cabell	..	..	..	..	..	..	..	..	..	..	2	..	1	..	..	..	..	..	..	..	3	..
Clay	..	..	..	..	..	..	..	..	..	..	2	4	..	2	..	..	..	..	..	..	2	6
Doddridge	..	..	..	..	..	..	..	..	1	1	3	3	2	2	1	1	..	..	..	..	7	7
Fayette	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	1	..
Greenbrier	..	..	..	..	..	..	2	..	6	..	25	..	43	..	36	..	8	..	4	..	124	..
Hardy	1	..	..	..	..	..	..	..	5	..	..	6	..	1	..	..	..	9	2	..	8	16
Hampshire	..	..	..	..	..	..	..	..	..	..	1	..	..	3	..	2	..	8	3	..	4	13
Harrison	..	..	..	..	..	..	..	..	2	3	11	26	4	10	..	..	..	..	..	..	17	39
Jackson	..	..	..	..	..	..	1	..	4	..	5	5	7	6	4	2	3	..	..	..	24	13
Jefferson	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	42*
Grant	2	..	..	..	..	..	..	..	5	..	7	..	..	5	..	12	..	34	..	..	12	54
Lewis	..	..	..	..	..	..	..	..	3	7	16	53	7	14	..	..	..	..	..	..	26	74
Lincoln	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	1	..
Marion	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..
Marshall	..	..	..	..	..	..	..	..	6	..	8	1	5	2	4	6	10	4	..	..	33	13
Mason	..	..	..	..	..	..	2	..	1	..	..	..	2	3	..	..	..	..	..	..	5	3
Mercer	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	24*
Mineral	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4	..	5	..	..	..	9	..
Mingo	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6	..	..	..	..	..	6	..
Monongalia	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	1	..
Monroe	..	..	..	..	..	..	4	..	8	..	3	..	30	..	19	..	3	..	2	..	69	..
Nicholas	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	..	..	..	..	5	..
Ohio	..	..	..	..	..	..	..	..	..	..	2	..	..	..	..	..	..	..	..	..	2	..
Pocahontas	..	..	..	..	..	..	..	..	1	..	5	..	69	..	143	..	37	..	5	..	260	..
Preston	..	..	1	..	..	..	..	..	1	..	..	3	10	1	..	..	7	..	..	..	19	4
Raleigh	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	1	..
Randolph	..	..	..	..	..	..	..	..	..	..	..	..	..	7	..	..	..	..	..	..	..	7
Ritchie	..	..	..	..	..	..	3	..	3	3	5	24	3	14	..	..	..	1	..	..	14	42
Roane	..	..	..	..	..	..	..	..	..	..	5	14	10	18	10	..	2	..	..	..	27	32
Summers	..	..	..	..	..	..	..	..	14	..	12	..	22	..	9	..	5	..	..	..	62	..
Taylor	..	..	..	..	..	..	..	..	..	..	3	1	3	4	..	..	..	..	..	..	6	5
Tyler	..	..	..	..	1	..	..	..	..	..	1	..	..	1	1	..	2	1	..	..	5	2
Upshur	..	..	..	..	..	..	..	..	..	1	..	19	..	8	2	1	..	..	..	..	2	29
Wayne	..	..	..	..	..	..	..	..	3	2	..	..	..	..	..	..	..	..	..	..	3	2
Webster	..	..	..	..	..	..	..	..	1	..	..	..	3	13	5	1	..	..	..	..	9	14
Wetzel	..	..	..	..	..	..	..	..	..	..	3	1	6	10	4	1	10	4	..	..	23	16
Wirt	..	..	..	..	..	..	..	..	4	..	3	..	1	..	..	..	..	..	..	..	8	0
Wood	..	..	..	..	..	..	..	..	2	..	5	4	5	2	1	1	..	..	..	..	13	7
Total	1	2	1	..	2	..	13	..	78	25	141	191	250	146	260	28	92	61	16	..	854	519

†None shipped during March and April, 1929. *Not distributed by months.
[1]Single deck. [2]Double deck.

In some sections of the state each independent dealer had taken a large area to himself and effectively kept other buyers from making purchases in his territory. This was accomplished through agreements between dealers to keep out of each other's territory. The agreements were enforced by means of retaliatory purchases at high prices if a buyer overstepped his territory. The livestock of the section was further controlled through the systems of contracting and of making loans on livestock which have been explained above.

Since records are not available, it is impossible to prove the truth or falsity of the accusations which were made against the dealers. Some farmers, however, were sufficiently dissatisfied with

the prevailing marketing conditions to join in the formation of cooperative associations.

During the period 1920-25 the Farm Bureau, not only in West Virginia but in many other states as well, was actively engaged in promoting commodity marketing organizations. This was a period of rapid growth of cooperative marketing. Furthermore, the Agricultural Extension Division was just beginning to expand its livestock program during 1922 and 1923. Since 1919 cooperative livestock shipping had experienced a rapid growth in the neighboring state of Ohio. In 1920 the farmers in that state had formed a new type of livestock marketing organization—the "County Unit Plan." Dissatisfied with the old system of marketing and spurred on by the rapid development of the cooperative movement in other states, and particularly that in Ohio, some West Virginia farmers were eager to organize, and cooperative shipping associations were formed rapidly over the state.

VOLUME OF BUSINESS

The growth in the number of shipping associations in West Virginia would be more favorable to the record of its cooperative movement were it not for the high mortality rate which has been experienced. Only 13 of the 21 associations which had been organized functioned in 1929. During 1930 there was a net gain of one over 1929, since three old associations were revived, but two which had shipped in 1929 were inactive in 1930.

A better picture of the changing fortunes of the cooperative associations may be formed from the data in Table 5, which shows the number of animals, by kinds, marketed by each association, each year from 1924 to 1930, and from data in Table 6, which shows the annual summaries for all associations.

The data presented in Tables 5 and 6 indicate that the associations have not been able to maintain a consistent growth in volume of business, some of them never having reached again the volume which they had during their first two years of operation. The total volume for all associations in the state decreased each year from 1925 to 1930.

Most of the associations increased their volume of business for two or three years, then took a decided slump, from which only a few have recovered in recent years. Others had a decreasing volume of business after the first year and finally ceased to function. This, however, is the course of development one might expect them to take, since dealer margins were probably decreased; some members of the cooperatives were paid more by the dealers than their livestock was worth, in an effort to kill off the association; disappointment with results, dissatisfaction with the management, and internal strife all worked to decrease the patronage after the first great effort at organization.

Changes in the total number of livestock in the state have un-

doubtedly had some effect on the volume of business, but this has not been nearly so important as the activity of the manager in listing livestock for shipment and the competition offered by independent dealers. Perhaps the biggest single problem of the cooperative shipping associations in the state has been to obtain capable and interested management.

TABLE 5—*Number of animals by kind and by years, marketed by cooperative livestock shipping associations*

County	Kind of animals	1924	1925	1926	1927	1928	1929	1930
Barbour	Cattle	188	42	....	....	22	17	22
	Calves	40	....	....	....	147	161	205
	Sheep and lambs	241	....	....	....	238	599	465
Braxton	Cattle	706	770	886	453	131	....	....
	Calves	....	....	453	77	151	60	....
	Sheep and lambs	1646	1401	2164	3520	3782	453	....
Doddridge	Cattle	....	206	313	27	....	....	129
	Calves	....	....	....	....	....	....	20
	Sheep and lambs	....	1264	1353	1000	192	....	1266
Fayette	Cattle	....	70	....	....	....	....	....
	Sheep and lambs	....	....	84	123	203	187	390
Greenbrier	Cattle	1480	1287	932	172	318	282	438
	Calves	....	....	201	2	....	7	77
	Sheep and lambs	989	1549	1074	1249	1463	1024	4486
Harrison	Cattle	....	428	145	....	110	....	30
	Calves	....	....	6	....	2	....	....
	Sheep and lambs	....	679	1281	790	734	765	524
Jackson	Cattle	317	117	48	....	....	20	....
	Calves	2	3	....	....	....	....	....
	Sheep and lambs	161	498	194	257	227	704	....
Lewis	Cattle	149	....	47	....	....	....	10
	Calves	....	....	....	....	....	....	5
	Sheep and lambs	454	750	1050	860	....	....	1526
Monroe	Sheep and lambs	....	1200	775	1044	....	....	....
Nicholas	Sheep and lambs	....	....	....	....	610	1124	1762
Pocahontas	Cattle	178	147	184	....	....	65	143
	Calves	....	....	18	1	....	7	28
	Sheep and lambs	2075	2911	2515	1351	468	2013	3155
Preston	Sheep and lambs	352	424	546	201	....	....	....
Randolph (Tygarts Valley)	Cattle	....	....	96	19	....	22	24
	Calves	....	....	....	2	....	2	6
	Sheep and lambs	....	....	315	357	269	236	184
Randolph (Middle Fork)	Sheep and lambs	....	....	....	....	....	872	1048
Ritchie	Cattle	969	955	676	71	57	53	917
	Calves	....	19	221	....	31	....	155
	Sheep and lambs	4189	2403	4046	2719	1271	1504	6203
Roane	Cattle	....	1070	1092	313	781	798	980
	Calves	....	244	404	36	185	211	683
	Sheep and lambs	....	475	586	777	1103	1462	3200
Tyler	Cattle	107	....	46	....	....	....	....
Upshur	Cattle	486	211	128	24	....	....	....
	Sheep and lambs	1670	997	988	1570	659	....	....
Wetzel	Cattle	....	44	29	....	27	....	....
	Calves	....	....	5	7	4	....	....
	Sheep and lambs	....	93	80	....	....	....	....
Wirt	Cattle	621	472	903	35	472	128	334
	Calves	618	857	99	289	94	401	914
	Sheep and lambs	1257	1158	991	1153	1074	1351	2749
Wood	Cattle	....	....	....	....	....	48	202
	Calves	....	....	....	....	....	....	160
	Sheep and lambs	....	....	....	....	....	649	987

The present inactivity of many of the associations which have been formed has been due to the lack of a capable man who was willing to manage the association. Most of the experienced and capable men who might have been available for managers were engaged in trading and trafficking in livestock on their own account and have shown little interest in giving up this business to assume the managership of a cooperative shipping association. The most successful associations in the state are those which have obtained the services of experienced independent dealers who, for the most part, have given up trading on their own account.

TABLE 6—*Summary of the business of all cooperative livestock shipping associations in West Virginia by years, 1924 to 1930, inclusive*

Year	Number of cattle	Number of calves	Number of sheep and lambs	Gross sales value	Net value to producers
1924	5201	660	13,034	$464,971.98	$420,501.23
1925	5819	1123	15,602	501,587.96	460,427.03
1926	5528	1407	18,042	501,501.12	461,262.08
1927	1114	414	16,971	270,456.05	251,955.24
1928	1918	614	12,293	288,794.79	268,070.00
1929	1433	894	12,943	244,227.38	224,535.01
1930	3229	2253	27,945	336,608.85	294,157.78

The volume of business of the associations has been affected by changes in the degree of competition which was offered by independent dealers as a result of changes in livestock prices. During periods of rising prices for livestock, there has been more active competition on the part of independent dealers and, therefore, fewer animals have been shipped through the cooperative associations. The increase in the price level for livestock has accounted in some measure for the decreased volume of business of many associations. This increase at least is a factor which must be considered when studying the changes in volume. During periods of falling prices for livestock, especially in the second year of falling prices, the independent dealers have offered less active competition. It appears to be a characteristic of them that during such periods they do as little contracting as possible and that price offers for future delivery may be well below the current prices. Some of them cease activity entirely. More farmers, therefore, give their business to the shipping associations for that year. In 1930, West Virginia was in its second year of falling livestock prices and this was largely responsible for the revival of the two old associations and the increased volume of business of almost all associations for that year.

The $501,000 worth of livestock marketed by cooperative shipping associations in West Virginia in 1925, the year of largest volume, is exceedingly small when compared with the $41,199,000 worth of livestock marketed by cooperatives in Missouri in 1925 *(8)*;* with the $11,000,000 business of cooperatives in Wisconsin in 1916 *(5)* and the $25,000,000 business in 1923 *(6)*; with the $69,000,000 busi-

*Reference is made by number (*italic*) to Bibliography, page 91.

ness of Minnesota cooperatives in 1919 *(2)*; with the 560 carloads of the Arkansas associations in 1920 *(7)*; or with the 67,523 single decks of livestock marketed by Iowa cooperative shipping associations in 1925 *(1)*.

When volume of business is measured in terms of gross value of livestock marketed, the average per association in West Virginia was $31,348 in 1925, the year of largest volume, and $16,282 in 1929, the year of smallest volume. The range was from the $172 business of the Wetzel county association in 1927 to the $154,794 business of the Greenbrier county association in 1924. The Roane county association is the only one to show a consistent growth since its organization, the volume of business being greater each year than in any preceding year, with the exception of 1927, when there was a large decrease in volume.

Cooperative associations marketed approximately five percent of the sheep and lambs and three percent of the cattle and calves sent from West Virginia to out-of-state markets in 1929. The estimate is made from data contained in Tables 3 and 4 and from Table 5. In order to arrive at an estimate of the number of animals marketed from the state, it was considered that a single deck contained 140, and a double deck 260 lambs; that 25 cattle or 90 calves equalled an average carload. To the number of animals thus obtained by converting the data on carloads to number of animals was added 15 percent, the estimated error due to incomplete records. The number of animals marketed from the state, estimated as indicated above, divided into the number of animals actually marketed by cooperative associations, gave the percentages referred to above.

The percentage of livestock produced in each county which was marketed by the cooperative associations is more significant than the percentage marketed cooperatively for the state as a whole, but the estimate is less reliable. By using the method explained above, the percentage of the total marketings from the county handled by each association in 1929 was estimated and is shown in Table 7.

After checking with several other estimates the percentages shown in Table 7 appear to be sufficiently accurate, with the exception of those for Fayette and Nicholas counties, to indicate the strength of the cooperative association in each county and the room for its expansion.

With the exception of the Wirt and Roane county associations, the cooperatives marketed a very small percentage of the livestock from counties in which they were operating. There are sufficient numbers of livestock in the counties to permit considerable expansion, if some of the obstacles indicated earlier can be overcome. It is thought by some people, however, that a larger volume of business would not contribute to the efficiency of the associations, and that those outside of the association profit as much and in the same manner as those patronizing the association. If both of these circumstances be true, then there is little use in putting forth the effort required for expansion. An attempt to answer these questions

is made later when an analysis of costs and prices is presented.

Not only is the volume of business of the cooperative shipping associations in West Virginia small, but the percentage of total marketings from the state also is small in comparison with cooperatives in Iowa, which shipped 24 percent of the livestock marketed in the state in 1924 *(1)*; with Minnesota cooperatives, which are estimated to have marketed 67 percent of all livestock shipped from points where associations were active in 1919 *(2)*; with Wisconsin associations, which shipped approximately 50 percent of all carloads of livestock marketed from the state in 1923 *(6)*; or with the Missouri cooperative associations, which marketed approximately 20 percent of the state's total in 1925 *(8)*.

TABLE 7—*Percentage of total out-of-state marketings of livestock handled by cooperative livestock shipping associations, by counties, 1929*

County	Percentage of cattle and calves	Percentage of sheep and lambs
Barbour	3	20[1]
Braxton	1	3
Fayette	..	100[2]
Greenbrier	6	5
Harrison	..	5
Jackson	0.6	10
Nicholas	..	160[3]
Pocahontas	3	5
Randolph	..	..[4]
Ritchie	3	11
Roane	27	12
Wirt	30	54[5]
Wood	4	18

[1] Barbour county trucked lambs to market; these were added to the railroad shipments to obtain total marketed from points within the county.

[2] and [3] Most of the livestock from Fayette and Nicholas counties was loaded at stations located in neighboring counties; therefore estimates on this basis are of questionable value.

[4] Complete records of railroad shipments not obtained for Randolph county.

[5] Practically all of the lambs marketed by the cooperative association in Wirt county were shipped with calves and there was no indication of the number of cars which were classified in freight records as cattle and which as lambs.

III. The Plan of Organization

THE COUNTY UNIT PLAN

Cooperative livestock shipping associations in West Virginia are organized according to the "County Unit Plan," a plan modelled after the County Unit plan developed and adopted by Ohio livestock shippers after an intensive study of cooperative livestock shipping organizations in Illinois, Kansas, Nebraska, Minnesota, Iowa, and Canada. It was thought that this type of organization would be better adapted to Ohio conditions than would be the local unit as found in most states where cooperative shipping was being carried on. The significant feature of the County Unit plan is that it includes a larger territory in its operations than the local shipping association. In some respects conditions of livestock production in West Virginia are similar to those in Ohio; consequently it was thought by those sponsoring the movement that the County Unit plan also was better adapted than the local unit plan to West Virginia conditions. The

shipping associations in West Virginia are non-stock bodies incorporated under the State Cooperative Marketing Act.

CONSTITUTION AND BY-LAWS

The constitution and by-laws are uniform for all associations in the state. They provide that the management of the county association shall be vested in a board of directors of five members. The president and vice-president are selected from the membership of the board of directors, but the secretary-treasurer may be selected from the membership at large. The membership of the county association may include any reputable person, residing in the county in which the association is organized or in an adjoining county, who is a paid-up member of his county Farm Bureau.

If a non-member of the county Farm Bureau wishes to make use of the shipping association, he may do so by paying the same rates of commissions as the Farm Bureau members pay, but he is not entitled to any patronage dividends, which may be made only to Farm Bureau members. At present this is a weak point in the organization, for the Farm Bureau in the state has lost heavily in membership, and in only a few cases have patronage dividends been paid. There is, therefore, little incentive for a farmer to join the Farm Bureau in order to become a member of the shipping association. In most counties little attention is given to membership in the associations, shipping being done for members and non-members on the same basis.

The Wirt county association was the only exception to the general policy of permitting non-members to ship without extra charge. This association charged 10 cents per hundredweight above the regular commission charges for marketing the livestock of non-Farm Bureau members, and also did not permit their participation in patronage dividends.

The "constitution" further provides that the liability of a member of the shipping association shall not exceed the amount of his annual Farm Bureau dues.

The following duties of the officers of the board of directors are set forth in the by-laws:

"1. To manage the affairs of the association, including the hiring or discharging of the county manager, and fixing his compensation.

"2. To meet once each month during the shipping season and in special meetings upon call of the president.

"3. To require bond of every person handling or having in custody money or anything of value on account of the association. Failure to require bond renders the directors personally liable to the association for any loss resulting from such neglect.

"4. To secure the services of a competent auditor for auditing and submitting a report to the board of directors of the records of the county manager and of the treasurer.

"5. To take membership in the West Virginia Cooperative Livestock Shipping Association, Inc., and to nominate a member from their own board to be seated on the board of directors of the state association."

The members of the board of directors are elected for three years, but no more than two come up for election in any one year. No person is eligible to be elected or to serve as a director if he is interested in or participates in a business in competition with the business of the county association.

The duties and powers of the county association manager as set forth in the by-laws are as follows:

"The duties of the county manager shall be actively to solicit business for the association; to be at the scales and yards on the day of shipment (unless he has secured a competent assistant) and receive all stock and weigh, properly mark, and load same on car; to have charge of and direct the sale of all shipments and receive all money therefor, and to pay same to the shippers, less the commission and other miscellaneous expenses connected with the shipment; to furnish a statement to each shipper showing the market weight, shrink, price received, and expenses; and to keep on file a complete record of each settlement on blank forms provided for such purpose.

"The county manager shall not buy livestock for himself or any other for shipment while he is in the employment of the association. The county manager shall keep the members of the association informed as to the market conditions and shall supply other information of value to them necessary to the successful operation of the association."

The duties and rights of members or consignees are as follows:

"Any person desiring to ship livestock through the association shall make such arrangements with his county manager, personally, by telegram or letter at least five days before he is ready to ship, giving the number and kind of livestock to be shipped, approximate weight, and date livestock will be delivered to the yards of the association for shipment. A member or consignee shall have the right to dispose of his livestock as he may wish, except that listed or promised for shipment through the association unless released by the county manager. In case any consignee is offered a price for his livestock which apparently is in excess of the net price that will be obtained by selling at the terminal market by the association, said consignee shall turn over the bid to the county manager, who shall handle it to the best interest of all concerned. In case a consignee orders space for shipment and fails to deliver his stock to the yards as per his agreements with the county manager, thereby causing loss to other shippers of the association, he shall be assessed the amount of the loss incurred. Failure to pay such loss shall bar the transgressor from further use of the association until such assessed loss has been paid.

"Any diseased animals and all stock which must be sold subject to inspection shall be received at the owner's risk and he shall receive such payment therefor as is received by the county manager, less all expenses figured prorata on the shipment. Any consignee whose stock is damaged after it is received by the county manager at the loading pens, or while in transit, shall receive the full value as though the stock had not been injured, but shall be subject to the same ratio of expense on the shipment. Any animal which is in a crippled or sick condition when delivered to the yards, shall be received at the owners' risk."

The "manager's commission" and "insurance fund", as provided in the by-laws, is fixed as follows:

"There shall be deducted on every hundred pounds of live weight of cattle, sheep, and hogs shipped an amount to be determined by the board of directors, which amount shall be used for the necessary expenses of the association, such as insurance for paying losses that may occur to stock from

the time it is received at the pens until final disposition is made of same; to pay the county manager for his services rendered to the association, and to pay the cost of the board of directors' meetings and other miscellaneous expenses."

"The county manager shall be paid for his services a certain sum per hundred pounds of live weight, taken at the terminal market, on cattle, sheep, and hogs, and the board of directors shall fix the amount.

"It shall be the policy of the board of directors to establish a reserve from the savings of the insurance fund and, if there is a surplus after establishing a reasonable reserve fund, to declare a patronage dividend at the close of each shipping season to the Farm Bureau members on the basis of per hundred pounds of livestock consigned to the association. The members of the board of directors and the county manager shall receive a compensation of three dollars per day for each regular or special meeting of the board of directors attended and in addition five cents per mile for each mile travelled to and from each regular or special meeting provided the board of directors actually transacts business for the association."

SOME PROVISIONS OF CONSTITUTION AND BY-LAWS NOT OBSERVED

The provisions in the constitution and by-laws have not been carried out fully at all times and in all counties. The provision for membership has been disregarded to a large extent. In some of the counties any one who consigns livestock to the association has come to be considered a member. The patronage dividend has been paid in only a few cases and there remains, therefore, little financial inducement for a patron to become a member of the association since the Farm Bureau has not always been active in each county. This leaves a large number of the patrons as non-members, and these feel no particular obligations to the shipping association.

The provision of the by-laws that no person shall be eligible for membership on the board of directors who is interested in any business competing with the association has not been observed in all cases. There have been some instances in the state where members of the board of directors were buying and shipping livestock on their own account in competition with the association. In most cases this has worked to the detriment of the association.

Not all of the county managers have kept as accurate records of the transactions of the associations as are provided in the by-laws. A large number have failed to weigh all livestock before shipment. Some have not preserved their records in such condition that they could be audited as specified in the by-laws. Nor have all county managers refrained from buying and selling livestock on their own account. This circumstance has limited the success of the association in some counties.

The provisions of the by-laws most frequently violated are those which specify that a member shall notify the manager as to the number, kind, approximate weight of livestock, and the time he wants to ship, and shall turn over outside bids to the manager. The failure of members to list their livestock with the manager has resulted in a heavy freight charge to other members because of light shipments. There is no case on record of members being forced to pay the extra

cost because of their failure to deliver livestock for shipment. Occasionally a member of the association has turned over a bid to the manager for livestock which he has agreed to ship. Often, however, the member uses the association as an alternative opportunity to make the independent dealer bid higher on his livestock.

RELATION OF COUNTY ASSOCIATION TO STATE ASSOCIATION

The county associations are federated into the West Virginia Cooperative Livestock Shippers' Association, Inc., with each county association having one representative on the board of directors. The functions of the state association are to promote cooperative shipping of livestock in the state; to assist the county associations in problems of production and marketing; and to advise with them concerning methods and costs of marketing so as to bring about uniformity of practices within the state. The state association is a member of the Producers' Co-operative Commission Association, of Pittsburgh, Pa. Through the state association the county associations also have membership in this commission firm, but the county associations are not required to market their livestock through it.

Each county association is supposed to send a monthly report of its business to the secretary of the state association and to pay membership dues of one cent per hundredweight, market weight, on all livestock marketed. The secretary of the state association is at present also the animal husbandman of the State Agricultural Extension Division, whose program dovetails so closely with the work of the state shipping association that it is impossible to separate some phases of the work of one organization from those of the other. In all of the undertakings of the shipping associations they are assisted by the county agricultural agents and members of the Agricultural Extension Division staff. Such assistance is given without cost to the cooperative association.

IV. The Aims of the Cooperative Livestock Shipping Associations in West Virginia

It is too much to say that even a majority of their patrons thoroughly understand the aims of the cooperative livestock shipping associations in West Virginia. Many of them look on such organizations as just another marketing agency to be used only when there appears to be some immediate advantage from patronizing them. Among the leaders, however, there is a well-defined purpose toward the accomplishment of which they are definitely working.

The central aim held by the leaders for these organizations is to procure for the producers the highest net return on their livestock enterprises that is consistent with the general conditions of the industry. To accomplish this purpose it is necessary to carry on two lines of endeavor: first, to return to the producer as large a proportion of the "terminal market dollar" as possible; and second, to improve the quality of the livestock of the state.

In order that the producer receive a larger share of the "terminal market dollar" than he would without the cooperative in the marketing field, the associations proceed along several lines of action. The first of these is found in the attempt to eliminate the profit of the independent dealers. The profit of the independent dealer is the difference between the terminal market selling price and the purchase price minus all expenses incident to his buying and selling. To eliminate this profit it is the purpose of the associations to market livestock at actual cost. This, however, may become a mere catch-phrase. Even though the association market the livestock at actual cost it does not necessarily follow that all or even a part of the profit which ordinarily goes to the independent dealer has been eliminated. If the profit is to be eliminated it is necessary that the actual marketing costs of the association be no larger than the costs of the competing independent dealer. If they are larger then only a part of the profit may be eliminated.

In attempting to eliminate the profit of the independent dealer it is necessary for the association not only to keep its money costs at least down to those of the competing dealer, but also to keep the shrinkage and loss from death and cripples at least down to the standard maintained by its competitors. This means the introduction of methods looking toward the proper handling of the animals while in transit to prevent injury, to procure a minimum of shrink, and to dispose of injured and dead animals to the maximum advantage.

But a larger proportion of a small "terminal market dollar" may be less than a smaller proportion of a larger terminal market dollar. The purchase price and the marketing costs are only two factors involved in determining the dealer's profit. The third factor is the selling price.

If the total marketing costs, including losses of the cooperative associations, are equal to those of competing dealers, their profit has not been eliminated unless the cooperative receive also as high a terminal market price. To obtain an equally high terminal market price, the cooperative must obtain equally good selling service on the terminal market and must be as well prepared as the independent dealer to ship to the proper market at the time the animals are in the proper condition to realize such a price.

If the marketing costs, the terminal sales price, and the price paid to the producer are equal for the cooperative association and the independent dealer, then the profit of the latter has been eliminated. This, however, is not the full purpose of the cooperative, for the costs of the competing dealer may be excessively high, or the sales prices may be excessively low. To realize their final goal the cooperatives must strive to lower marketing costs to the minimum in keeping with the service offered and to increase the sales price to the maximum in keeping with the quality of the animals sold.

The second line of endeavor to increase the net returns to the producer lies in bringing about an improvement in the quality of the livestock. This leads the cooperatives into what is essentially a

production program. Endeavors to improve quality make little headway against methods of purchase used by independent dealers, who give quality little consideration in their price offers. If satisfactory results are to be obtained from efforts to improve quality of livestock, it is necessary that differences in quality be registered by differences in the price to the producers. Hence, if a cooperative is to return the highest possible net price to its patrons, it is necessary that its program for improvement in quality be accompanied by a method of payment such that the price, as it is affected by quality on the terminal market, be registered with the producer. This means that the livestock of each patron must be sold and paid for on a quality basis.

The aims of the cooperative associations are in keeping with sound principles in the economy of marketing livestock. The efficiency of West Virginia's cooperative shipping associations must be measured by the extent to which these aims have been realized. It is unfortunate that sufficient data are not available with which to measure accurately the extent of the accomplishments. It is possible to present some data for this purpose but it is necessary to resort to deductive reasoning to arrive at anything like a complete measure. An attempt to measure the accomplishments of the cooperative shipping associations in West Virginia is made in the following chapters.

V. The Costs of Marketing Livestock Through Cooperative Shipping Associations in West Virginia

Data on the cost of marketing livestock in years before the organization of cooperative shipping associations are not available. Neither has it been possible to obtain marketing cost data from independent dealers in the state, chiefly because none of them has kept an accurate record of his costs. It is therefore impossible to make a comparison of shipping association costs with the costs of marketing which prevailed before their organization, or with the marketing costs of their competitors, the independent dealers. It is possible, however, to show the amount of the various items entering into the total marketing cost of the shipping associations, and to form some judgment as to the reasonableness of these and the economy of the services which call for such expenditures. It is also possible to make a comparison of the net farm price received from each agency of marketing. If the cooperatives compete successfully with the independent dealers, it may be assumed that the latter will be forced to take a margin about equal to the total marketing cost of the associations, and to pay the farmer as much as the net price he would receive by marketing through the association.

In the following pages an analysis is made of the marketing costs of shipping associations, the services rendered, the economy of the services, and a comparison of prices received by producers from

sales to the private dealer with those of sales through the cooperative associations.

The items of cost and the total cost of marketing sheep and lambs, cattle, and calves through the various cooperative shipping associations in the state are shown in Tables 8, 9, and 10, respectively. The costs were calculated from the records of the associations and were based on market weights of the animals sold. The costs on a few carloads which were marketed by the associations were not included because of inadequate records, and costs of two or three associations had to be omitted entirely. The rate of each item of

TABLE 8—*Average costs per cwt. for marketing sheep and lambs through cooperative livestock shipping associations, by counties and items of cost, 1924 to 1929, inclusive*

County	Transportation	Yardage	Feed	Selling commission	Total terminal market cost†	Manager's commission	Insurance fund	Local car expense	Total home expense	Total marketing expense
	(*cents*)	(*cents*)	(*cents*)	(*cents*)	(*cents*)	(*cents*)	(*cents*)	(*cents*)	(*cents*)	(*cents*)
Barbour	102	10	004	30	142	09	12	01	22	164
Braxton	56	12	03	27	98	14	06	12	22	120
Greenbrier	54	11	05	22	92	07	02	..	09	101
Harrison	49	11	05	23	88	13	04	07	24	112
Jackson	48	11	05	18	82	14	06	02	22	104
Nicholas	69	13	06	25	113	12	05	11	28	141
Pocahontas	65	10	04	19	98	12	05	01	18	116
Roane*	46	11	06	17	80	11	08	03	22	102
Wirt	52	10	04	22	88	10	08	05	23	111

*Transportation costs, yardage, and selling commission were calculated on basis of animals going to market. Some animals were sold locally, or f. o. b., on which only home expenses were charged.

†Terminal market cost is the sum of transportation, yardage, feed, and selling commission costs.

expense as shown in the tables is an average of the cost per hundredweight on animals marketed by the associations from 1924 to 1929 inclusive. There has been little change in any of the fixed rates during this period. Of course, feed cost has varied somewhat but it is one of the small items of expense. The sum of these cost items represents the entire marketing cost to the producer with the following exceptions: (a) insurance on terminal market, which amounts to 15 cents per carload; (b) shrinkage; and (c) the expense of getting the animals to the shipping point, which is borne by the owner. The fee paid into the insurance fund covers insurance in transit. The producer also is reimbursed out of this fund for any loss due to death or injury of animals.

The average amount of each item of cost of marketing sheep and lambs for the various associations is shown in Table 8.

THE COST OF MARKETING SHEEP AND LAMBS

The total cost of marketing sheep and lambs as shown in Table 8 ranged from $1.01 per cwt. for the Greenbrier county association to $1.64 per cwt. for the Barbour county association. The total cost

for each of the other associations was between these two extremes, but for the majority it was nearer the former figure. With these costs, the percentage of shrink, and the market quotations known, it is possible to calculate the approximate price which the producer should receive at the shipping point. Shrink, of course, is a variable factor, but calculations of the shrink on sheep and lambs marketed by the cooperatives show that it was on the average about 11 percent. (Table 28.) If, therefore, lambs of a certain quality were selling on the terminal market for $15 per cwt., the net price for such lambs received by a patron of the Greenbrier county association would have been, on an average, $2.66 per cwt. below the terminal market price, but for a patron of the Barbour county association it would have been $3.29 below the terminal market price. If, for the same service, independent dealers in these respective counties were taking on the average higher margins, then it was costing the producers more to market their livestock through them than it would if they patronized the shipping association. Since shrink is so important an item in determining the amount of the margin, that margin which is necessary to meet the marketing costs will vary with the terminal market price, being greater when the price is high than when it is low.

If during this period a dealer operated on the same margin, and rendered the same service as the cooperative association, he would have had, in Greenbrier county, only nine cents per cwt., but in Barbour county 22 cents out of which to pay his local expenses and to derive his profits. These amounts represent the sum of the cost items for manager's commission, insurance fund, and local car expense. Out of these sums would come all of the local expense incident to buying, shipping, and payment for losses, but not shrinkage. Good management might permit some reduction in transportation cost, yardage, and selling commission. If, therefore, it is found that a dealer is paying prices and rendering services equal to those of the cooperative associations, it may be assumed either that he has reduced his marketing costs by efficient management; that he has managed to sell on a higher market; or that his profit margin is reasonably small. If he is less efficient in all of these matters then he must be operating at a loss.

The total marketing cost on sheep and lambs of the Barbour county association was 62 percent higher than that of the Greenbrier association. Transportation cost was included in this total cost. A more accurate comparison of the operating efficiency may be had, however, if this item be eliminated. With the item of transportation cost eliminated, the Nicholas association becomes the high-cost association with a remaining total cost of 72 cents per cwt. as compared with 47 cents per cwt. for the Greenbrier unit. The sum of the remaining cost items for the former association was 53 percent higher than for the latter. Even with the cost of transportation eliminated, the difference in the amount of the remaining costs does not necessarily measure a difference in efficiency of the associa-

tions. It becomes necessary to analyze the separate items of cost for each association; this is done further on.

THE COST OF MARKETING CATTLE

The total cost for marketing cattle through the cooperative associations is shown in Table 9. As in the case of sheep and lambs, the items of cost are averages for the cattle marketed by each association from 1924 to 1929, inclusive. Calculations were made on the same basis as those indicated for sheep and lambs.

TABLE 9—*Average cost per cwt. for marketing cattle through cooperative livestock shipping associations, by counties and items of cost, 1924 to 1929, inclusive*

County	Transportation	Yardage	Feed	Selling commission	Total terminal market cost[1]	Manager's commission	Insurance fund	Local car expense	Total home expense	Total marketing expense
	(*cents*)	(*cents*)	(*cents*)	(*cents*)	(*cents*)	(*cents*)	(*cents*)	(*cents*)	(*cents*)	(*cents*)
Barbour	52	05	05	17	79	09	09	03	21	100
Braxton	41	05	05	16	67	07	06	03	16	83
Greenbrier	46	03	06	11	66	06	01	..	07	73
Harrison	27	04	06	11	48	09	05	04	18	66
Jackson	37	03	07	13	60	05	06	01	12	72
Pocahontas	50	04	05	15	74	08	06	..	14	88
Roane	36	04	05	11	56	07	05	02	14	70
Wirt	38	05	06	12	61	10	05	02	17	78

[1] Terminal market cost is the sum of transportation, yardage, feed, and selling commission costs.

The total marketing cost on cattle amounted to $1 per cwt. for the Barbour county association, the high-cost unit, which was 51 percent more than the 66-cents cost of the Harrison county association, the low-cost cooperative. With transportation cost eliminated, the range of the sum of the remaining costs was from 27 cents per cwt. for the Greenbrier association, which becomes the low-cost association, to 48 cents per cwt. for the Barbour association, which remains the high-cost association, that of the latter being approximately 80 percent higher than that of the former.

As in the case of sheep and lambs, the total cost does not include the item of shrink. The average shrink on cattle marketed through the associations was approximately seven percent (Table 28). If cattle of a certain quality were selling on the terminal market for $10 per cwt., a patron of the Barbour association would have received for such cattle, on the average, $1.70 per cwt. less than the terminal market price, while a patron of the Harrison association would have received $1.36 less. The home expenses of the Greenbrier organization, which was low in respect to these items, amounted to seven cents per cwt., but for the Barbour unit they amounted to 21 cents. This was the amount competing dealers would have had out of which to meet their local expenses if they were paying a price equal to the cooperative price. Table 9 shows that there was considerable variation between associations in the various items of cost for marketing cattle.

THE COST OF MARKETING CALVES

The average amount of the different items of cost and the total cost of marketing calves through the various cooperative associations are shown in Table 10. The same qualifications apply to these data as have been indicated for those pertaining to sheep and lambs and cattle.

The total marketing cost for calves, as shown in Table 10, ranged from an average of 83 cents per cwt. for the Greenbrier association to $1.72 per cwt. for the Barbour cooperative, the cost of the latter being 104 percent higher than that of the former. Shrink amounted, on the average, to about nine percent (Table 28).

If calves of a certain quality were selling on the terminal market for $15 per cwt., a patron of the Barbour association would have received for that quality of calves approximately $3 per cwt. less than the terminal market price, while a patron of the Greenbrier association would have received on an average only $2.10 per cwt. less.

TABLE 10—*Average cost per cwt. for marketing calves through cooperative livestock shipping associations, by counties and items of cost, 1924 to 1929, inclusive*

County	Transportation	Yardage	Feed	Selling commission	Total terminal market cost[1]	Manager's commission	Insurance fund	Local car expense	Total home expense	Total marketing expense
	(cents)	*(cents)*	*(cents)*	*(cents)*	*(cents)*	*(cents)*	*(cents)*	*(cents)*	*(cents)*	*(cents)*
Barbour	112	11	01	27	151	11	09	01	21	172
Braxton	73	12	03	22	110	07	06	03	16	126
Greenbrier	47	04	06	15	72	09	02	..	11	83
Pocahontas	51	03	04	15	73	10	06	..	16	89
Roane	52	07	04	16	79	10	06	05	21	100
Wirt	51	12	02	16	81	10	05	04	19	100

[1] Terminal market cost is the sum of transportation, yardage, feed, and selling commission costs.

If the cost item for transportation be eliminated, the Barbour association remains the high-cost association, with a cost of 60 cents per cwt., and the Greenbrier association low, with a cost of 36 cents per cwt., the remaining cost of the former association being 66 percent higher than that of the latter. The home marketing expenses ranged from 11 cents per cwt. for the Greenbrier cooperative to 21 cents for the Roane and Barbour county associations.

MARKETING COSTS IN WEST VIRGINIA COMPARED WITH THOSE IN OTHER STATES

Reports of studies of cooperative shipping associations in other states show few cost data with which comparisons may be made. In Minnesota *(2)* the total marketing cost for 146 associations in 1917 was 29.1 cents per cwt., of which 19.6 cents was for freight and central market expenses and 9.5 cents for home expenses. Both the

home and central market expenses were considerably higher for the West Virginia than for the Minnesota associations.

The reports of some studies attempt to portray the efficiency of cooperative shipping associations by using as a measure the percentage of the gross sales value returned to the producer. This method is less accurate than one which shows the items of marketing cost in monetary terms. The total cost of marketing is composed, for the most part, of relatively fixed cost rates, which do not vary with the price of livestock. With cost rates fixed, the percentage of the gross sales value returned to the producer varies directly with the price of the livestock marketed. When livestock prices are high the producer will receive a larger percentage of the gross sales value than when prices are lower. By this method, therefore, the efficiency of one association cannot be compared adequately with that of another even within the same state, or within the same year, because there may be differences both in the grade of livestock marketed and in the charges on the various terminal markets. All of these factors tend to lessen the significance of such a comparison.

TABLE 11—*Percentage of gross sales returned to the producer by cooperative livestock shipping associations, by association and year, 1924 - 1929, inclusive**

Association	1924	1925	1926	1927	1928	1929
	(percent)	*(percent)*	*(percent)*	*(percent)*	*(percent)*	*(percent)*
Barbour	88.2	89.1	..	..	86.9	72.5
Braxton	92.9	89.6	92.7	93.5	91.1	88.1
Doddridge	..	90.6	93.6	91.5	88.6	..
Fayette	..	85.0	86.9	90.9	90.3	91.1
Greenbrier	90.0	91.2	91.8	93.0	94.6	94.1
Harrison	..	91.7	91.3	95.9	93.3	92.1
Jackson	92.6	91.3	92.9	90.6	89.4	89.4
Lewis	88.1	99.2[1]	98.8[1]	98.4[1]	..	..
Monroe	..	100.0[1]	97.9[1]	90.3	..	..
Nicholas	..	..	..	..	88.4	88.8
Pocahontas	91.4	95.9	89.4	90.9	90.9	89.4
Preston	96.6	99.5[1]	93.7	100.0[1]	..	..
Randolph (Tygarts Valley)	..	..	93.6	91.3	99.1[1]	90.5
Randolph (Middle Fork)	..	..	..	..	..	98.2[1]
Ritchie	92.0	93.1	92.5	93.6	94.4	92.0
Roane	..	90.2	91.0	95.3	94.6	94.1
Tyler	87.4	..	93.6	..	..	..
Upshur	88.9	91.2	90.6	90.6	91.2	..
Wetzel	85.5	86.6	88.7	82.6	63.2	..
Wirt	87.4	89.7	88.6	90.8	89.9	91.1
Wood	..	..	..	..	..	92.0
Average	90.4	91.8	92.0	93.0	93.0	92.0

*Calculated from records of Secretary, West Virginia Cooperative Livestock Shipping Association, Inc. Does not include patronage dividends.
[1]Sold locally.

Since this method has been used in some studies of cooperative shipping associations and, in the absence of other data, is of some value for comparative purposes, the percentage of gross sales value returned to the producer by the various cooperative associations in West Virginia is shown in Table 11.

It may be observed from Table 11 that there was considerable variation in the percentage of gross sales value returned to the pro-

ducer, both as between associations and years. Undoubtedly some of this variation was due to a difference in expenses. The average percentage of gross sales value returned to patrons of all cooperative shipping associations in the state ranged from 90.4 percent in 1924 to 93 percent in 1927 and 1928, but in 1928 the Wetzel county association returned only 63.2 percent. These percentages do not include patronage dividends which, if added, would increase the percentage slightly. This is about the same percentage as that reported for cooperative associations in Wisconsin when in 1923 they returned to the producer an average of 92 percent of the gross sales value *(6)*.

An analysis of the separate cost items for each association is presented in the following pages.

AN ANALYSIS OF TRANSPORTATION COSTS BY ASSOCIATIONS

Tables 14 to 22, inclusive,* show the transportation costs per cwt. for the various kinds of livestock marketed by cooperative shipping associations in West Virginia. The data for some associations were not available. The number of animals shown in the tables does not, in every instance, equal the number marketed by each association, as some animals were sold locally, some were sold f. o. b. shipping point, and of some the records were not accurate enough for use. The data, however, are for a very large percentage of all animals marketed by the associations. According to data in these tables, the percentage increase in actual transportation cost above minimum available cost was largest for sheep and calves, while cattle in most counties were transported at a cost near the minimum rate.

The increases in transportation costs were due primarily to three factors: small volume of business, inability to load up to the minimum weight set by the railroads, and poor management. Many of the associations attempt to market all livestock offered to them. They do this as a matter of supplying a service which enables the producers to send their livestock to market when it is ready to go. The small volume of business in conjunction with the attempt to give this service results in light loadings, mixed loads, and, in some

*Column 1 in Tables 14 to 22 shows the years for which data are presented; column 2, the number of animals on which transportation was paid; column 3, the market weight of the animals included in column 2; column 4, the actual sum paid for transportation on these animals to the various markets; column 5, the average transportation cost per cwt.; column 6, the rate per cwt. at which the animals could have been shipped by railroad to the same markets to which they were shipped, provided (1) that the sheep were shipped in double-deck cars and loaded so as to reach minimum weight, (2) that calves were loaded up to minimum weight and shipped in double-decks or with loads of cattle which reached the minimum weight, and (3) that cattle were loaded so as to reach the minimum weight. Column 7 shows the total transportation cost if animals had been transported at minimum rate as given in column 6. Column 8 shows the excess of the actual transportation cost above the minimum cost given in column 7. Column 9 shows the percentage the excess in transportation cost was of the minimum cost. Column 10 shows the increased cost per cwt. due to failure to transport at minimum rate. Data in columns 9 and 10 are the important ones in this series of tables.

cases, shipments by truck. If each association could have had a sufficient volume of business to ship a full carload of one kind of animal once or twice each week during the marketing season, it could have given adequate service and at the same time could have transported the livestock at the minimum rate. The minimum weight for which freight rates are shown in Tables 14 to 22 is 18,000 pounds for a double-deck of sheep; 22,000 pounds for a double-deck of calves; and 22,000 pounds for a carload of cattle. Shippers assert that it was practically impossible to load enough lambs in a car to reach the minimum weight of either a single or double deck. In view of this, therefore, the lowest rate which the shippers could obtain was somewhat higher than the minimum shown in Tables 14 to 22 for sheep and lambs, even though there were a sufficient volume to permit full loadings.

TABLE 12—*Average weight of carloads of livestock shipped by cooperative associations, by kind of shipment*

County association	Cattle alone	Cattle and calves	Sheep single deck	Sheep double deck	Sheep and calves single deck	Sheep and calves double deck	Calves alone	Cattle, calves, sheep
Braxton	22,476	22,435	9835	16,000	11,160	.....	8810	.....
Greenbrier	25,677	22,964	8470	17,123	.....	.....	....	.....
Harrison	24,764	24,190	8765	14,707	.....	.....	....	.....
Jackson	19,270	.....	8377	13,262	.....	.....	....	.....
Nicholas	.....	.....	8940	.....	.....	.....	....	.....
Pocahontas	23,130	16,530	9493	15,430	.....	.....	....	.....
Roane	24,578	23,750	9265	15,355	9,650	15,925	....	19,073
Wirt	20,461	17,439	7946	.....	11,071	16,800	8845	15,190

The average weight of the carloads of livestock loaded by the various associations is shown in Table 12. The averages were calculated on the basis of all livestock shipped by each association since 1924. These averages are significant in an analysis of the transportation costs of the various associations, because they indicate either a lack of sufficient volume for the most economical transportation, or poor management, or both.

Table 13 shows the percentage of the animals transported in various kinds of shipments. It is evident from the data in the table that a large proportion of the animals were transported in mixed shipments, which played a part in increasing the transportation costs.

1. The Braxton County Association

The transportation costs on livestock marketed by the Braxton county association are shown in Table 14.

It cost the Braxton association an average of 9.8 cents per cwt., or 21.8 percent, more to transport its sheep and lambs to market than it would have cost to send them to the same markets if they had been transported at the minimum rate available. For a patron shipping 50 lambs of average weight this meant a loss of approximately $4. An analysis of the records of the association shows that

TABLE 13—*Percentage of total number of animals shipped by cooperative associations transported by designated kind of shipment, 1924 to 1929, inclusive*

Association	Cattle alone	Cattle with calves	Cattle with sheep	Cattle with sheep and calves	Calves alone	Calves with cattle	Calves with sheep	Calves with cattle and sheep	Calves by truck	Sheep alone single deck	Sheep alone double deck	Sheep with calves	Sheep with cattle	Sheep with cattle and calves	Sheep by truck
Barbour	....	...	..	100.0	...	....	3.6	5.5	90.9	...	...	15.4	..	2.2	82.4
Braxton	22.7	77.2	..	....	59.1	34.8	5.9	..	...	9.8	88.4	1.6	..	..	...
Greenbrier	84.9	15.1	..	....	...	89.3	10.7	..	...	18.6	77.8	3.7	..	..	...
Harrison	73.5	22.7	3.8	....	...	100.0	...	..	1.4	29.3	67.3	...	2.0	..	...
Jackson	100.0	...	..	....	...	....	...	..	...	36.8	63.2	...	..	..	...
Nicholas	...	...	..	....	...	....	...	..	...	13.9	86.1	...	..	..	...
Pocahontas	45.2	54.8	..	....	...	100.0	...	..	...	28.4	71.6	...	..	..	...
Roane	53.8	42.0	..	4.2	9.2	77.7	5.5	7.6	...	18.0	76.1	3.9	..	2.0	...
Wirt	44.6	46.6	..	8.8	16.7	7.5	66.7	9.1	...	21.7	3.0	66.8	..	8.5	...

this increased cost was the result of shipments by single deck, 9.8 percent being shipped to market in this manner; and light loading and shipment of calves and lambs together, 1.6 percent being thus shipped. When lambs and calves are shipped together the load takes the sheep **rate** and the calf-minimum **weight.** It appears, however, to be difficult to load to the minimum weight in such a shipment. It is obvious from data presented in Table 12 that the average weight of the loads of lambs shipped by this association was much below the minimum fixed by the railroads in the case of

TABLE 14—*Transportation costs on livestock marketed by the Braxton county association, by years, compared with costs if livestock had been transported at minimum freight rates by railroads*

Year	Number of animals	Market weight (pounds)	Total transportation cost	Transportation cost per cwt. (cents)	Minimum freight rate per cwt. (cents)	Total transportation cost at minimum rate	Increased transportation cost above min. cost	Percentage increase in transportation cost	Increased trans. cost per cwt. above min. rate (cents)
SHEEP AND LAMBS									
1927	3512	230,190	$1266.83	55.0	45.0	$1046.53	$220.30	21.0	9.5
1928	3368	210,210	1158.95	55.1	45.8	964.81	194.14	20.0	9.3
1929	453	28,190	176.31	62.5	46.3	130.78	45.53	34.8	16.2
Total	7333	468,590	$2602.09	55.5	45.7	$2142.12	$459.97	21.4	9.8
CALVES									
1927	75	12,315	$ 103.29	83.8	43.9	$ 54.08	$ 49.21	90.9	39.9
1928	140	21.180	134.34	63.4	43.7	92.64	41.70	45.0	19.7
1929	52	9,165	75.15	82.0	44.0	40.32	34.83	86.0	38.0
Total	267	42,660	$ 312.78	73.3	43.8	$ 187.04	$125.74	67.2	29.5
CATTLE*									
1927	190	195,505	$ 796.27	40.7	41.0	$ 802.82	$ -6.55	...	-00.3
1928	113	102,528	429.56	41.8	41.2	423.02	6.54	...	00.6
Total	203	298,033	$1225.83	41.1	41.1	$1225.84	.....	...	...

*No cattle marketed in 1929.

single deck and double-deck, as well as in mixed shipments of calves and sheep. The average weight of the single decks was 9,835 pounds, of the double-decks 16,000 pounds, and of the mixed shipments of calves and sheep 11,160 pounds.

The transportation cost for calves was 29.5 cents per cwt., or 67.2 percent, more than the minimum rate available. Fifty-nine percent of the calves were shipped in straight shipments, 34.8 percent with cattle, and 5.9 percent with sheep. This increased cost was the result of light loading and mixed shipments, particularly of calves with lambs. The average weight, 8,810 pounds, of a few straight shipments of calves was far below the minimum for even a single deck. It is possible to ship calves with cattle without increasing the rate above the cattle rate, provided there is not a sufficient number of calves to prevent loading to the minimum cattle weight.

Cattle were transported on an average at a cost near the minimum rate. Only 22.7 percent were marketed in straight cattle shipments, while 77.2 percent were shipped with calves. The number of cattle marketed was not large, but it is easier to load them to the minimum weight. The manager of the association is also more likely to refuse to ship cattle if a full load is not available. Table 12 shows that the average weights of shipments of both cattle and mixed shipments of cattle and calves made by this association were a little more than the minimum requirements to procure the minimum rate.

2. The Greenbrier County Association

The transportation costs on livestock marketed by the Greenbrier association are shown in Table 15.

It cost the Greenbrier county association 7.4 cents per cwt., or 15.9 percent, more than the minimum rate to transport its lambs to market. This increased cost was also due to shipments by single deck, 18.6 percent being thus transported; light loading; and mixed shipments of lambs and calves, 3.7 percent of which were thus transported. A larger percentage of the lambs were shipped in double-decks by this association than by most of the others. It may be observed from Table 12 that the average weight of the single-deck loads, 8,470 pounds, was considerably below the minimum, but that the average weight of the double-deck loads, 17,123 pounds, was well up to the minimum.

The calves were shipped with cattle and loaded in such a way as to obtain the minimum cattle rate. Likewise, shipments of cattle were transported at the minimum rate. The management of this association has been able to transport cattle and calves at the minimum rate available, but has failed to keep transportation costs to the minimum on sheep and lambs.

3. The Harrison County Association

The transportation costs on livestock marketed by the Harrison association are shown in Table 16.

TABLE 15—*Transportation costs on livestock marketed by the Greenbrier county association, by years, compared with costs if livestock had been transported at minimum freight rates on railroads*

Year	Number of animals	Market weight (pounds)	Total transportation cost	Transportation cost per cwt. (cents)	Minimum freight rate per cwt. (cents)	Total transportation cost at minimum rate	Increased transportation cost above min. cost	Percentage increase in transportation cost	Increased trans. cost per cwt. above min. rate (cents)
SHEEP AND LAMBS									
1923	1705	114,225	$ 682.94	59.8	47.5	$ 542.56	$140.38	25.8	12.3
1924	988	69,585	419.42	60.3	47.5	330.53	88.89	26.8	12.8
1925	1549	107,660	607.84	56.5	47.5	511.38	96.46	18.8	9.0
1926	1074	73,110	387.76	53.0	47.5	347.27	40.49	11.6	5.5
1927	1249	88,280	446.38	50.6	47.5	419.33	27.05	6.4	3.1
1928	1463	96,545	531.65	55.0	47.5	458.59	73.06	15.9	7.5
1929	1025	72,345	309.07	42.7	42.7	309.07	.....	...	...
Total	9053	621,750	$3385.06	54.4	47.0	$2918.73	$466.33	15.9	7.4
CALVES									
Total*	770	150,880	$ 701.59	46.5	46.5	$ 701.59	.....	...	...
CATTLE									
Total*	5505	6,236,261	$28,514.89	45.7	45.7	$28,514.89	.....	...	...

*Complete record by years not available.

The Harrison association paid an average of 12.5 cents per cwt., or 34.4 percent, more than the minimum rate to transport its sheep and lambs to market. This increased cost was due to light loadings and some shipments by single deck. By referring to Table 12 it may be seen that the average weight of both single and double decks of lambs shipped was considerably below the minimum neces-

TABLE 16—*Transportation costs on livestock marketed by Harrison county association, by years, compared with costs if livestock had been transported at minimum freight rates on railroads*

Year	Number of animals	Market weight (pounds)	Total transportation cost	Transportation cost per cwt. (cents)	Minimum* freight rate per cwt. (cents)	Total transportation cost at minimum rate	Increased transportation cost above min. cost	Percentage increase in transportation cost	Increased trans. cost per cwt. above min. rate (cents)
SHEEP AND LAMBS									
1925	375	25,675	$ 138.81	54.1	41.6	$ 106.90	$ 31.91	29.8	12.5
1926	948	62,902	302.49	48.1	36.3	228.21	74.28	32.5	11.8
1929	765	47,975	224.33	46.8	33.3	159.80	64.53	40.4	13.5
Total	2088	136,552	$ 665.63	48.7	36.2	$ 494.91	$170.72	34.4	12.5
CATTLE									
1925	404	390,110	$1045.88	26.8	26.7	$1041.96	$ 3.92	00.4	0.1
1926	162	171,150	457.53	26.7	26.4	453.49	4.04	00.9	0.3
Total	566	561,260	$1503.41	26.7	26.6	$1495.45	$ 7.96	00.4	0.1

*Minimum rate is for double decks of sheep and calves.

sary to obtain the minimum freight rate. The average weight of single decks shipped by this association was 8,765 pounds and of double decks 14,707 pounds. Cattle and calves were transported at the minimum rate available.

4. The Jackson County Association

The transportation costs on livestock marketed by the Jackson association are shown in Table 17.

Records were available for only one year's business of the Jackson association. During this year it cost the association 15.7 cents per cwt., or 48 percent, more to market its sheep and lambs than the minimum rate available, and 2 cents per cwt., or 5.7 percent, more to market its cattle. These increased costs, again, were the result of light loadings and shipments by single deck. The average weight of all shipments was considerably below the minimum weight for that kind of shipment. A patron shipping 50 lambs of average weight would have lost more than $6 because of this increased transportation cost, while one shipping a thousand-pound steer would have lost 20 cents.

TABLE 17—*Transportation costs on livestock marketed by the Jackson county association, by years, compared with costs if livestock had been transported at minimum freight rates on railroads*

Year	Number of animals	Market weight (pounds)	Total transportation cost	Transportation cost per cwt. (cents)	Minimum freight rate per cwt. (cents)	Total transportation cost at minimum rate	Increased transportation cost above min. cost	Percentage increase in transportation cost	Increased trans. cost per cwt. above min. rate (cents)
SHEEP AND LAMBS									
1929	710	43,280	$209.46	48.3	32.6	$141.45	$68.01	48.0	15.7
CATTLE									
1929	20	19,270	$ 71.30	37.0	35.0	$ 67.45	$ 3.85	5.7	2.0

5. The Nicholas County Association

Table 18 shows the transportation costs on livestock marketed by the Nicholas association.

The transportation cost on sheep and lambs marketed by the Nicholas association was 15.2 cents per cwt., or 28.3 percent, more than the minimum freight rate. An analysis of the records of this association shows that the increase was caused by light loading and shipments in single rather than double decks. All shipments were in single decks which averaged only 8,940 pounds, considerably below the minimum weight of 18,000 pounds necessary to obtain the minimum rate on double-decks, on which these calculations were based.

6. The Pocahontas County Association

In Table 19 the transportation costs on livestock marketed by the Pocahontas association are given.

TABLE 18—*Transportation costs on sheep and lambs marketed by the Nicholas county association, by years, compared with costs if livestock had been transported at minimum freight rates on railroads*

Year	Number of animals	Market weight (pounds)	Total transportation cost	Transportation cost per cwt. (cents)	Minimum freight rate per cwt. (cents)	Total transportation cost at minimum rate	Increased transportation cost above min. cost	Percentage increase in transportation cost	Increased trans. cost per cwt. above min. rate (cents)
1928	610	37,755	$260.90	69.0	53.0	$200.52	$ 60.38	30.0	16.0
1929	1123	69,530	477.81	68.7	53.9	374.81	103.00	27.0	14.8
Total	1733	107,285	$738.71	68.8	53.6	$575.33	$163.38	28.3	15.2

For the Pocahontas cooperative the average transportation cost for sheep and lambs was 17.9 cents per cwt., or 37.7 percent, above the minimum rate; 7.8 cents, or 18.2 percent, above, for calves; and 7.1 cents, or 16.4 percent, above, for cattle. An analysis of the records of this association shows that the increase in transportation cost on sheep and lambs was due to light loading and shipment by single deck; on calves and cattle it was due to light loads of mixed shipments of cattle and calves. The average weights of various kinds of loads shipped by this association are given in Table 12.

TABLE 19—*Transportation costs on livestock marketed by the Pocahontas county association, by years, compared with costs if livestock had been transported at minimum freight rates on railroads*

Year	Number of animals	Market weight (pounds)	Total transportation cost	Transportation cost per cwt. (cents)	Minimum freight rate per cwt. (cents)	Total transportation cost at minimum rate	Increased transportation cost above min. cost	Percentage increase in transportation cost	Increased trans. cost per cwt. above min. rate (cents)
SHEEP AND LAMBS									
1926	1048	70,400	$ 480.27	68.2	47.5	$ 334.40	$145.87	43.6	20.7
1927	1503	103,490	677.68	65.0	47.5	491.58	186.10	37.8	17.5
1928	360	22,580	211.86	94.0	47.5	107.25	104.61	97.5	46.5
1929	2013	129,928	766.05	58.9	47.5	617.16	148.89	24.1	11.4
Total	4924	326,398	$2135.86	65.4	47.5	$1550.39	$585.47	37.7	17.9
CALVES									
1926	13	3,570	$ 19.63	55.0	44.5	$ 15.88	$ 3.75	23.6	10.5
1929	7	1,220	4.64	38.0	38.0	4.64	.....	...	...
Total	20	4,790	$ 24.27	50.6	42.8	$ 20.52	$ 3.75	18.2	7.8
CATTLE									
1926	19	16,200	$ 89.10	55.0	44.5	$ 72.09	$ 17.01	23.6	10.5
1929	65	58,330	285.53	48.9	42.8	249.74	35.79	14.3	6.1
Total	84	74,530	$ 374.63	50.2	43.1	$ 321.83	$ 52.80	16.4	7.1

7. The Wirt County Association

Table 20 gives the transportation costs on livestock marketed by the Wirt county association.

For the Wirt association the transportation cost on sheep and lambs was increased 17.9 cents per cwt., or 51.9 percent, above the minimum freight rate chiefly because of light loading, shipments by single deck, and mixed shipments of lambs and calves. The transportation cost for calves was increased 16.3 cents per cwt., or 47.5 percent, for the same reasons. A large percentage of the business of this association consisted of the marketing of lambs and calves

TABLE 20—*Transportation costs on livestock marketed by the Wirt County Cooperative Livestock Shippers' Association, by years, compared with costs if livestock had been transported at minimum freight rates on railroads*

Year	Number of animals	Market weight (pounds)	Total transportation cost	Transportation cost per cwt. (cents)	Minimum freight rate per cwt. (cents)	Total transportation cost at minimum rate	Increased transportation cost above min. cost	Percentage increase in transportation cost	Increased trans. cost per cwt. above min. rate (cents)
SHEEP AND LAMBS									
1925	981	62,170	$ 294.21	47.3	34.5	$ 214.48	$ 79.73	37.0	12.8
1926	1058	66,420	383.04	57.6	34.5	229.15	153.89	67.1	23.1
1927	1163	73,270	373.97	51.0	34.5	252.78	121.19	47.9	16.5
1928	1075	64,780	369.76	57.0	34.5	223.49	146.27	65.0	22.5
1929	1306	83,025	412.37	49.6	34.5	286.44	125.93	43.9	15.1
Total	5583	349,665	$1833.35	52.4	34.5	$1206.34	$627.01	51.9	17.9
CALVES									
1925	1012	167,775	$ 752.82	44.8	34.5	$ 578.82	$174.00	30.0	10.3
1926	595	96,437	518.71	53.7	34.5	332.71	186.00	55.9	19.2
1927	289	50,625	297.99	58.8	34.5	174.66	123.33	70.6	24.3
1928	472	80,720	429.36	53.2	34.5	278.48	150.88	54.0	18.7
1929	401	70,255	372.08	52.9	34.5	242.38	129.70	53.5	18.4
Total	2769	465,812	$2370.96	50.8	34.5	$1607.05	$763.91	47.5	16.3
CATTLE									
1925	458	381,690	$1427.01	37.3	33.8	$1290.93	$136.08	10.5	3.5
1926	274	203,510	780.17	38.3	34.5	702.11	78.06	11.1	3.8
1927	35	31,580	151.34	47.9	34.5	108.95	42.39	38.9	13.4
1928	94	82,650	301.43	36.5	34.5	285.14	16.29	5.7	2.0
1929	128	108,655	415.92	38.2	34.5	374.86	41.06	10.9	3.7
Total	989	808,085	$3075.87	38.0	34.1	$2761.99	$313.88	11.3	3.9

and most of them were sent to market in mixed, single-deck shipments, thus adding materially to the transportation cost. A part of this increase undoubtedly was due to poor management, while a larger part may be attributed to the small volume handled by the association, coupled with its frequent shipments. The transportation cost on cattle was increased 3.9 cents per cwt., or 11.3 percent, above the minimum freight rate by light loading and a few mixed shipments of cattle and lambs.

8. The Roane County Association

The transportation costs for livestock marketed by the Roane association are shown in Table 21.

The average transportation cost for sheep and lambs marketed by the Roane association was 11.4 cents per cwt., or 32.6 percent, above the minimum freight rate; for calves it was 17.1 cents per cwt., or 49 percent; and for cattle it was only 0.8 of a cent per cwt., or 2.2 percent, above. The increased cost on sheep and lambs was due primarily to light loadings; shipments by single deck; during the earlier years of the association an occasional mixed shipment of lambs and calves; and in later years to the practice of a combination of truck and boat transportation. The increased cost for transporting calves was due to light loads of mixed shipments of lambs and calves and also to the transportation by truck and boat referred to above. The slightly increased transportation cost for cattle was due to light loadings of mixed shipments.

TABLE 21—*Transportation costs on livestock marketed by the Roane county association, by years, compared with costs if livestock had been transported at minimum freight rates on railroads*

Year	Number of animals	Market weight (pounds)	Total transportation cost	Transportation cost per cwt. (cents)	Minimum freight rate per cwt. (cents)	Total transportation cost at minimum rate	Increased transportation cost above min. cost	Percentage increase in transportation cost	Increased trans. cost per cwt. above min. rate (cents)
SHEEP AND LAMBS									
1925	44	3,180	$ 14.72	46.3	35.0	$ 11.13	$ 3.59	32.3	11.3
1926	574	37,000	161.43	43.6	35.0	129.50	31.93	24.7	8.6
1927	483	31,600	126.43	40.0	35.0	110.60	15.83	14.3	5.0
1928	983	58,820	302.25	51.3	35.0	206.16	96.09	46.6	16.3
1929	1346	80,785	376.88	46.6	35.0	282.74	94.14	33.0	11.6
Total	3430	211,385	$ 981.71	46.4	35.0	$ 740.13	$241.58	32.6	11.4
CALVES									
1925	301	60,635	$ 228.41	37.7	35.0	$ 212.22	$ 16.19	7.6	2.7
1926	379	67,545	268.08	39.7	35.0	236.41	31.67	13.4	4.7
1927	73	13,210	67.97	51.5	35.0	46.24	21.73	47.0	18.5
1928	175	31,200	272.17	87.2	35.0	109.20	162.97	149.2	52.2
1929	200	34,720	244.60	70.4	35.0	121.53	123.07	101.0	35.4
Total	1128	207,310	$1081.23	52.1	35.0	$ 725.60	$355.63	49.0	17.1
CATTLE									
1925	963	819,800	$2962.12	36.1	35.0	$2869.30	$ 92.82	3.2	1.1
1926	742	681,550	2448.99	35.9	35.0	2385.42	63.57	2.7	0.9
1927	88	86,000	301.00	35.0	35.0	301.00	.....	...	...
1928	429	402,965	1436.83	35.6	35.0	1410.37	26.46	1.7	0.6
1929	509	478,710	1679.59	35.8	35.0	1675.48	4.11	2.2	0.8
Total	2731	2,469,025	$8828.53	35.8	35.0	$8641.57	$186.96	2.2	0.8

It may be seen from Table 21 that the transportation cost on sheep, and especially on calves, increased markedly during 1928 and 1929. This large increase was due to the higher cost of truck and boat transportation, as compared with the cost by rail'road. During the early part of the shipping season, when the volume was too small for carload shipments, the manager of this association transported calves and lambs by truck from Spencer to Parkersburg, a distance of 48 miles. They were then loaded on a boat which took them to

the Pittsburgh market. This practice greatly increased the transportation cost. It is defended by the management, however, on the basis of the higher price which the producer received because of placing the animals on the market at their proper stage of development, and at a season when market prices are usually somewhat higher. Sufficient data are not available with which to prove or disprove this contention. The fact remains that a larger volume of business would permit the same service without this increase in transportation cost.

9. The Barbour County Association

Table 22 shows the transportation costs on livestock marketed by the Barbour association.

The records of only two years were available for the Barbour association, but for these years the transportation cost on sheep and lambs was 65.6 cents per cwt., or 178.2 percent, above the minimum freight rate; for calves it was 75.9 cents per cwt., or 207.1 percent above; and for cattle 15.5 cents per cwt., or 42.4 percent above.

TABLE 22—*Transportation costs on livestock marketed by the Barbour county association, by years, compared with costs if livestock had been transported at minimum freight rates on railroads*

Year	Number of animals	Market weight (pounds)	Total transportation cost	Transportation cost per cwt. (cents)	Minimum freight rate per cwt. (cents)	Total transportation cost at minimum rate	Increased transportation cost above min. cost	Percentage increase in transportation cost	Increased trans. cost per cwt. above min. rate (cents)
SHEEP AND LAMBS									
1928	212	14,531	$167.57	115.3	36.5	$ 53.03	$114.54	216.0	78.8
1929	618	42,495	414.96	97.6	36.5	156.29	258.67	165.0	60.8
Total	830	57,026	$582.53	102.1	36.5	$209.32	$373.21	178.2	65.6
CALVES									
1928	136	22,525	$255.47	113.4	36.5	$ 82.21	$173.26	210.0	76.9
1929	161	23,880	266.26	111.4	36.5	87.66	178.60	203.0	74.7
Total	297	46,405	$521.73	112.4	36.5	$169.87	$351.86	207.1	75.9
CATTLE									
1928	21	14,780	$ 70.94	48.0	36.5	$ 53.94	$ 17.00	31.5	11.5
1929	16	13,050	73.79	56.5	36.5	47.63	26.16	54.9	20.1
Total	37	27,830	$144.73	52.0	36.5	$101.57	$ 43.16	42.4	15.5

For a patron marketing 50 lambs of average weight through this association, if there were no other compensations, the loss due to this increased transportation cost would have been approximately $26; for one marketing a 150-pound veal calf the loss would have been $1.14; for one marketing a 1,000-pound steer the loss would have been $1.55. Practically all of this increase in transportation cost may be attributed to shipments by truck. The county is situated approximately 150 miles from Pittsburgh, where the livestock was marketed. The management trucked practically all of the livestock

to market during 1928 and 1929. The practice was also continued by this association during 1930, and two or three of the other associations began it. The arguments used to justify the practice are: (1) convenience to farmer; (2) lower terminal market cost; (3) less shrink; (4) animals arrive in better shape; and (5) cost no more than by rail.

10. Costs of Trucking Livestock to Market

The practice of trucking to market has not been followed in West Virginia for a sufficient length of time to provide data with which to analyze these contentions, but it has been studied in other states. That transportation by truck is a convenience to producers, appears to be the only contention which is well founded in fact, and this convenience might well be provided at a lower cost by trucking the animals only to the railroad shipping point, then sending them on by rail. From data in Table 10 it is evident that there was a saving only in the item of feed cost for the Barbour association, and this saving was comparatively small.

A study of marketing livestock by truck in Ohio *(4)* indicates that transportation rates by truck were higher than freight rates into the Cleveland market and about the same as freight rates into the Cincinnati market; also, that buyers may discriminate against trucked-in livestock because of the unusual fill such animals often carry.

The report of a study of trucking livestock to market in Indiana *(10)* says: "With average figures, including all costs of the transportation of hogs from farm to market by each method, it seems that there would be a point somewhere between 30 and 90 miles at which the cost would be identical. Beyond this point it would become a question of how much the added convenience and flexibility of the truck are worth to the farmer in comparison to the railroad costs."

The following quotation taken from Minnesota "Farm Business Notes" *(11)* indicates the tentative conclusions concerning trucking costs in Minnesota: "In shipping by rail the farmer must assume the additional cost of transporting livestock from the farm to the shipping point. To hire this service from local truckers will cost on the average about ten cents per cwt. . . . . Furthermore, shipping by truck eliminates some of the local expenses of the shipping association or local buyer. The local expenses, including manager's salary, for cooperative shipping associations usually amount to at least eight cents per cwt. . . . . The terminal market charges of yardage and commission are higher for trucked-in livestock . . . . . Livestock arriving by truck are usually not fed at the terminal market, while on rail shipments there is the additional cost of feed. The rates of insurance against loss in transit are slightly lower for truck shipments than for rail shipments on distances up to 100 miles. No complete information is available on comparative shrinkage of livestock shipped by rail and truck." A table showing a comparison of

truck and freight rates given in the Minnesota publication indicates that freight rates from the same points are consistently lower than truck rates.

The Iowa Agricultural Experiment Station has also given some attention to the growing practice of marketing livestock by truck in that state. Fitzgerald says *(1)*:

"It is not difficult to see the advantages of trucking directly to market. It saves the farmer the time and trouble of getting the stock to the local shipping point, and returns are received more quickly. The former may be of great benefit to him, especially during the busy seasons of the year. The disadvantages of trucking are numerous and many of them are not so obvious. In the first place, hauling by truck is usually more expensive, often being three times as high as the cost by rail to the same market. Secondly, trucking engenders the feeling that no shrink is incurred, because the farmer usually has no home weight with which to check his market weight. Such information as is available tends to show that while shrink from trucked hogs is not as large as that received when the stock is shipped by rail, it is at least two-thirds as large. . . . .

"A third important disadvantage of the truck is the irresponsibility and carelessness of many of the private operators. In many cases they are operating on a 'shoe-string' and losses from accidents or carelessness cannot be collected even if it were legally possible to do so. At present no provision has been made for the control of these carriers or for making them responsible for the livestock while it is in their care. There has been considerable complaint, too, of mistakes made in the returns. Farmers are often paid for a smaller or larger number of hogs than they loaded on the truck, simply because the truck operator has not been careful in making out his returns. Another fact that the livestock shipper has to take into consideration is that the 'market', especially the local packers, usually discriminates against trucked hogs and pays 10 to 30 cents less for them than for carload lots of the same weight and quality, because of the greater expense involved in handling and accounting for the smaller lots and because the packers have found that these hogs carry a larger fill and do not have as high dressing percentage."

Further study is necessary before a definite statement can be made as to the ultimate economy of trucking livestock to market. Results in other states indicate, however, that managers of West Virginia cooperative shipping associations may well be extremely cautious of adopting such a practice. Some associations in the state are trucking to the shipping point at a cost of about 10 cents per cwt. This service may well be expanded before resorting to trucking from farm to market.

11. Summary of Transportation Costs

The transportation cost on lambs and calves has been increased for all of the associations chiefly because of light loadings and mixed shipments. It is impossible to determine how much of this is due to poor management and how much to the small volume of business. A small volume of business undoubtedly gives rise to marketing practices which increase the transportation costs above the minimum available rate. Most of the managers are aware of this, but in attempting to render service to their patrons they are hampered by the small volume. As indicated earlier a part of the increased transportation cost on the lambs was due to the inability to load

them up to the minimum weight. By no means can all of the increase in transportation cost be attributed to this factor, for data presented in Table 12 show that the average weight of the loads was greatly below the minimum.

There appears to be a tendency for the increase in transportation cost to vary inversely with the number of animals shipped by the association. There is no clear correlation, because in some cases a manager will stop when he has one or two carloads and if he cannot obtain another full car he will not ship. This factor makes it possible for some of the associations with a small volume to transport their livestock to market as efficiently as an association with a larger volume. An association which attempts to ship at regular periods is the one whose transportation costs are most likely to be increased by its small volume. On the other hand, an association which ships the livestock of its members to market at the time the animals are best fitted to move may be rendering improved service which more than offsets the increased freight costs. The private dealer has an advantage over the cooperative in this respect because he can call for delivery of the livestock which he has purchased in sufficient quantities to load a car to the minimum weight.

The transportation cost is clearly affected by volume of business especially if the association attempts to put animals on the market at their proper stage of development. The volume of business of the shipping associations in West Virginia has been too small to realize the greatest economies in transportation and at the same time render the proper service to its patrons.

TERMINAL MARKET COSTS

Terminal market costs include charges for feed, yardage, insurance, and selling commission. The amount of these costs is largely beyond the control of the management of the cooperative shipping association. Yardage cost is on a per-head basis, and selling commission charges are based on the carload or on the head. In analyzing costs, however, comparison is easier if these are converted to a hundredweight basis.

The variations in terminal market costs between the associations as shown in Tables 8, 9, and 10 were due to differences in rates charged on the various markets; to a difference in the weight of animals marketed; and to the kind and weight of shipment: i. e., whether a straight or mixed shipment, and whether a light or heavy load.

1. Feed Costs

The average feed cost on sheep ranged from 0.4 of one cent per cwt. for the Barbour county association to 6 cents per cwt. for the Roane and Nicholas associations. The variations in this cost among the other associations were not great. The low feed cost for the Barbour association was due to the fact that practically all of its

lambs were trucked and, therefore, not fed at the terminal market. This is one item that should be credited to the cost of transportation by truck. The saving, however, is small. Since the feed costs given in Table 8 are averages for a period of years, the varying price of feed caused a slight difference in the average feed cost per cwt. in each association due to the fact that each unit did not have the same relative volume of business each year. However, the differences in the cost of this item arising from the circumstance were small. With the exception of the Barbour association the differences in feed costs were due primarily to the method of prorating expenses on mixed shipments. The expenses were prorated for each carload separately on a hundredweight basis. If lambs and calves were marketed in the same load the total market expense was divided by the total market weight of the load. Calves and lambs were then assessed at the same rate per cwt. When, therefore, calves were marketed with cattle, the feed cost assessed to the calves was higher, and that to the cattle, lower than if they had been marketed in straight loads, because calves do not consume as much feed per cwt. as do cattle.

The average feed cost of the various associations for calves ranged from 1 cent to 6 cents per cwt.; for cattle the range was from 5 cents to 7 cents; and for sheep and lambs it was from 0.4 of one cent to 6 cents. Feed cost is a minor part of the total marketing expense.

TABLE 23—*Yardage rates on terminal markets to which West Virginia cooperative livestock shipping associations send livestock*

Kind of animals	Jersey City	Pittsburgh	Baltimore	Lancaster
Cattle	40 cents per head	33 cents per head	40 cents per head, maximum $12 per car	$1.25 per head, not to exceed $30 per car
Calves	20 cents per head	300 pounds or under, 20 cents per head	20 cents per head, maximum $20 per car	10 cents per head
Sheep	8 cents per head	7 cents per head	8 cents per head, maximum $20 per car	5 cents per head

2. Yardage

The yardage rates charged on the terminal markets to which the cooperative associations shipped their livestock are shown in Table 23.

The Lancaster market had the lowest yardage rates on sheep and calves, while the Pittsburgh market had the lowest rate on cattle. The yardage costs shown in Tables 8, 9, and 10 are on the basis of hundredweight rather than head, and are averages for all animals shipped by each association. The average yardage cost per cwt. on sheep and lambs ranged from 10 cents for three associations to 13 cents for one association; for cattle it ranged from 3 cents for two associations to 5 cents for three associations; and for calves

from 3 cents for one association to 12 cents for two associations. Since yardage charges are based on the head, when they are converted to a hundredweight basis they will vary inversely with the weight of the animals. It is evident from yardage rates quoted in Table 22 that it is possible to decrease the yardage rates slightly on theBaltimore market by heavy loading, because there is a limit to the amount that may be charged per car. For instance, by loading more than 250 lambs in a car the rate would be decreased slightly because the maximum charge is $20 per car, which is just equal to 250 head at 8 cents per head. There is no opportunity to make a large decrease in the rates, however. On the other markets there is no chance for reduction by heavy loading.

The average yardage costs per cwt. for each association as shown in the tables are not the same as would have been paid on straight shipments, since the costs shown are averages of the actual sums paid by the patrons who marketed through the cooperatives. Differences in the yardage cost in straight shipments and the cost actually paid by the patrons are due to the method of prorating expenses on mixed shipments. When cattle and calves are shipped together the yardage cost prorated to cattle is a bit higher than if they had been shipped alone. While the total yardage cost on the entire shipment is not increased, that part which the patron pays on cattle is slightly higher. When sheep and calves are shipped together, the yardage paid by the patron on sheep may also be slightly higher. The difference to the patron between the yardage cost on straight shipments and on mixed shipments was not great. Most patrons shipped some of each kind of animals and in the long run the differences between yardage cost in straight and mixed shipments may have about evened up. The difference between associations in the average cost per cwt. as shown in the tables was due to the different proportions of the cars which were mixed shipments; to the proportionate number and weight of the various kinds of animals in the mixed shipments that were marketed by the various associations; and to the difference in yardage rates of the various markets.

Since the yardage rates are based on the head, the number of animals in a car and the weight of the load have no effect on the total yardage cost, except in the case of the Baltimore market, where there is a maximum charge per car. This maximum is seldom exceeded. Neither management nor volume of business, therefore, affect the total cost of this item. But both poor management and small volume of business, when they result in mixed shipments, affect the proportion of the total yardage cost which each individual patron pays.

3. Selling Commission

The rates charged for selling livestock on the various markets to which the cooperative associations shipped are given in Table 24.

Table 24 shows that the rate of the selling commission is on a somewhat different basis for each of the markets to which West Virginia associations shipped. On the Jersey City market, in the

case of cattle, the sales value is a factor in determining the commission charged per head, but the commission is based entirely on the head for sheep and calves. There is no maximum limit per car for the selling commission on this market. On the Pittsburgh market the selling commission on all kinds of animals is based entirely on the head without reference to value, but with a maximum charge per car. On the Baltimore market, also, the selling commission for cattle is based on the head, but with a maximum charge per car which is higher than on the Pittsburgh market, while the commission on sheep and calves is based on the gross sales value, with no maximum charge per car.

TABLE 24—*Selling commission rates on terminal markets to which West Virginia cooperative livestock shipping associations ship livestock*

Kind of Animals	Jersey City	Pittsburgh[1]	Baltimore[2]
Cattle	Sales value $20 or over, $1.25 per head; sales value under $20, 75 cents per head	$1.25 per head, not to exceed $25 per car	$1.25 per head, not to exceed $30 per car
Calves	30 cents per head	40 cents per head, not to exceed $15 per single deck and $28 per double deck	2 percent on gross sales
Sheep	15 cents per head	25 cents per head, not to exceed $15 per single deck and $25 per double deck	2 percent on gross sales

[1]Calves with sheep not to exceed $18 per single deck. Calves with cattle not to exceed $28 per car.
[2]Cows $1 per head for those selling below $20 per head.

The total charges for selling were prorated to the patrons of the association on the basis of hundredweight of animals shipped in the car. In the case of mixed shipments the same sort of analysis would apply to the selling commission costs as has been presented for yardage costs, with the rate paid by the patrons being affected by the method of prorating employed.

The average selling cost per cwt. on sheep which was charged to the patron ranged from 17 cents in the Roane county association to 30 cents in the Barbour association. Both the Barbour and Roane associations marketed their sheep and lambs on the Pittsburgh market. The large difference in selling cost was due to an increased rate for selling the trucked shipments of the Barbour association.

The average selling cost on calves ranged from 15 cents per cwt. for the Greenbrier and Pocahontas county associations to 27 cents for the Barbour association. On cattle the average selling cost ranged from 11 cents per cwt. for three associations to 17 cents for the Barbour association. The average selling cost for each association was shown in Table 8.

With so many factors involved it is well-nigh impossible to explain what part of the variations in selling cost between the associations was due to a particular factor. The proportion of mixed shipments and the proportion of the different kind of animals in each

mixed shipment; on some markets the weight of the animals and the total weight of the carload; and on some markets the value of the animals,—all affected the cost per cwt. which the patrons paid.

Small volume of business and poor management, resulting in mixed shipments, had no effect on the total amount of the sales commission charged except on the Pittsburgh market. On this market it is possible for a mixed shipment of calves and sheep to increase the selling commission $3 per single deck and for calves shipped with cattle to increase it by the same amount. (See Note 1, Table 24.) Trucking to this market will, however, greatly increase the total amount of the selling commission. For example, the typical truckload of lambs sent to market by the Barbour association contained 33 lambs. The selling commission amounted to 25 cents per head. The maximum charge for selling a double-deck is $25. The usual double deck shipped from West Virginia contains about 250 lambs. On this basis the selling commission amounts to 10 cents per head, or 15 cents per head less than on trucked-in lambs. For lambs weighing 75 pounds at the market, there is a difference then of approximately 20 cents per cwt. In the same manner, trucking to the Pittsburgh market increases the total selling commission on calves.

Livestock shipped by the cooperative associations to the Pittsburgh market was sold by the Producers Cooperative Commission Association, of which The West Virginia Cooperative Livestock Shipping Association, Inc., is a member. Practically all of the livestock shipped by the Barbour, Jackson, Roane, and Wirt county associations, and a part of that by the Harrison and Braxton county associations, went to this market, while that from the other associations was sold on the Baltimore, Lancaster, or Jersey City markets. There were no cooperative commission firms on these latter markets. Some of the private commission merchants made an extra charge of 25 cents per shipper for prorating the terminal market expenses. These charges were included in the calculations of the commission charges.

HOME EXPENSES

Home expenses include charges for "insurance fund", manager's commission, and local car expense. An analysis of these costs for each association is presented below.

1. Insurance Fund

The rate of insurance fund authorized by each association is shown in Table 25.

The insurance fund rate is not the same for all of the associations. The rate is fixed by the board of directors of each county association, but on the advice of the state association it is kept more or less uniform. Not all managers assessed the full amount of the rate permitted by the association. As shown in Table 25, the insurance fund varies with the ownership of the shipment, whether

one or more patrons own the animals in the shipment. The rate actually charged the patron may be somewhat different from the rate authorized because of the method used for prorating the expenses of mixed shipments. The average insurance fund rates per cwt. collected by the associations are shown in Tables 8, 9, and 10. The average rate collected on sheep and lambs ranged from 2 cents per cwt. for the Greenbrier county association to 12 cents per cwt. for the Barbour association; on calves the range was from 2 cents charged by the Greenbrier association to 9 cents by the Barbour association; and on cattle from 1 cent collected by the Greenbrier association to 9 cents by the Barbour association. The average rate collected by the other associations was between these extremes.

Money collected as insurance fund constituted the larger part of the gross income; in fact the entire gross income of most of the associations. Occasionally, due to inaccurate calculations, there was a slight gain in prorating which added to the income of the association. The Wirt association charged 10 cents per cwt. for marketing the livestock of non-Farm Bureau members, as well as a small weigh fee, which also added to its income.

TABLE 25—*Rate of insurance fund authorized by boards of directors of cooperative shipping associations, by counties, 1929*

County association	CATTLE		CALVES		SHEEP AND LAMBS	
	Single owner car	Multiple owner car	Single owner car	Multiple owner car	Single owner car	Multiple owner car
	(*Cents per cwt.*)	(*Cents per cwt.*)	(*Cents per cwt.*)	(*Cents per cwt.*)	(*Cents per cwt.*)	(*Cents per cwt.*)
Barbour	5	6	5	6	5	6
Braxton	5	6	5	6	5	6
Greenbrier	2	2	2	2	2	2
Harrison	5	6	5	6	5	6
Jackson	5	6	5	6	5	6
Nicholas	5	6	5	6	5	6
Pocahontas	5	5	5	5	5	5
Roane	3	6	3	6	3	6
Wirt	5	5	5	5	5	5

For the most part, however, the operating expenses of the cooperative associations were paid out of insurance fund collections. The manager is supposed to pay the full amount of the insurance fund to the treasurer of the association as soon as the account for each shipment is closed. Unfortunately, the treasurers of most of the associations have kept such meager and unintelligible records that it was impossible to analyze the expenditures of this fund. Many records have been lost entirely. While the by-laws of the associations authorize an annual audit of both the manager's and treasurer's accounts, in most instances the treasurers have failed to submit an account that could be audited.

The following items of expense were the common ones which were paid out of the insurance fund: (1) to the state association, dues of 1 cent per cwt. on all livestock marketed; (2) payments for loss due to death or injury of animals while in transit; (3) payments for stationery, scale books, postage, and other current operating ex-

penses; (4) payments for losses in prorating; (5) payments for directors' meetings of county and state associations. Such payments constitute the bulk of the expenses of the association. A few associations have made contributions to assist the state association in livestock improvement work, and some associations have paid patronage dividends, which came out of the insurance fund.

A partial list of patronage dividends which have been paid by county associations is shown in Table 26. This may not be a complete list, but it does constitute the bulk of the patronage dividends which have been returned by the associations.

TABLE 26—*Patronage dividend payments*

County association	Year	Amount
Doddridge	1925	$ 60.15
Upshur	1926	52.38
Wirt	1925	77.05
Ritchie	1927	175.00
Roane	1925	110.79
Roane	1929	185.63
Greenbrier	1924	450.00
Pocahontas	1924	61.52

If this list is reasonably accurate there is evidence that in recent years the expenses of the associations have consumed most of the money collected as insurance fund. Because of the lack of sufficient data it is impossible to analyze the cause of this circumstance. The associations should be careful to keep their operating expenses reasonable and wherever possible return a patronage dividend, even though it be a small one. With the exception of payments for directors' meetings, the operating expenses are of such a nature that they should vary directly with the volume of business.

From the few data available it appears as though not more than ten percent of the insurance fund collections was paid to patrons for dead and injured animals.

2. Local Car Expense

The average of local car expense on sheep and lambs varied from nothing in the Greenbrier county association to 12 cents per cwt. in the Braxton association; on cattle it varied from nothing in the Greenbrier and Pocahontas associations to 4 cents in the Harrison association; and on calves from nothing, again in the Greenbrier and Pocahontas associations, to 5 cents in the Roane association. The average local car expense per cwt. for each association and for each kind of animals is shown in Tables 8, 9, and 10, from which it may be observed that there was a wide variation in this expense between the associations. As a rule the cost of rope and partitions was charged to the account of local car expense. Some associations charged costs of driving to the local car expense account, while in other associations each patron was responsible for the delivery of his animals to the shipping point. Whenever partitions are required for mixed shipments the local car expense is increased, and this was

the cause of the comparatively large "local car expense" of some associations. In these cases small volume, resulting in mixed shipments, added to the charges designated as local car expense.

3. Manager's Commission

The rate of the manager's commission as authorized by the various associations is shown in Table 27.

As shown in Tables 8, 9, and 10, respectively, the average amount of manager's commission collected per cwt. on sheep and lambs ranged from 7 cents in the Greenbrier association to 14 cents in the Braxton and Jackson associations; on cattle it ranged from 5 cents in the Jackson association to 10 cents in the Wirt association; and on calves it ranged from 7 cents in the Braxton association to 11 cents in the Barbour association. The differences between associations in the average amount per cwt. collected as manager's commission were due to: (1) a difference in the rates authorized by the board of directors; (2) a difference in the proportion of single ownership shipments; (3) a difference in the proportion of mixed shipments and kind of mixed shipments; and (4) the fact that some managers did not always charge the full commission rate authorized.

TABLE 27—*Rate of manager's commission authorized by boards of directors of cooperative shipping associations, by counties, 1929*

County association	CATTLE		CALVES		SHEEP AND LAMBS	
	Single owner car	Multiple owner car	Single owner car	Multiple owner car	Single owner car	Multiple owner car
	(Cents per cwt.)	*(Cents per cwt.)*	*(Cents per cwt.)*	*(Cents per cwt.)*	*(Cents per cwt.)*	*(Cents per cwt.)*
Barbour	5	10	5	10	7	14
Braxton	5	10	5	10	8	15
Greenbrier	5	10	5	10	5	10
Harrison	5	10	5	10	7	14
Jackson	5	10	5	10	7	14
Nicholas	5	10	5	10	7	14
Pocahontas	5	10	5	10	8	15
Roane	5	10	5	10	7	14
Wirt	5	10	5	10	5	10

Managers of West Virginia cooperative livestock shipping associations are paid entirely on the basis of hundredweight of livestock sold by the association. The total amount of their pay, therefore, varies directly with their volume of business. There is little uniformity among such cooperatives in the United States in the methods of paying their managers, but payment on the hundredweight basis appears to be the most common practice. Of 115 cooperative associations reporting to a questionnaire in Minnesota *(2)*, 103 were paying the managers on the basis of hundredweight of livestock shipped; all but 2 of these were paying the same rate for all species of livestock shipped. The rates in 1919 ranged from 5 to 15 cents, with 68 percent of the associations paying from 6 to 8 cents. Seven of the 115 associations were paying by the carload, the amount ranging from $15 to $18. Two associations were paying their managers $150 per month and one association was paying $5 per day. Of the 71 associations for which manager's earnings were

given, only 45 percent of the managers received less than $1,000 per year.

In Iowa "the average manager's fee in those associations in which the manager does all the prorating was, in 1925, 5.7 cents per cwt.; in the associations in which the manager prorates the home expense only, 5.7 cents; in the associations in which the manager does not prorate, 5.6 cents per hundredweight." *(1)*

In Wisconsin "the commonest payments are 6 cents, 8 cents, or 10 cents a hundredweight for all classes alike." *(6)* Some associations, however, pay on a car basis, and others on an hour, day, or month basis.

In Ohio the manager receives a commission of 8 to 12 cents per cwt. on livestock shipped. *(9)*

It appears that the rate of the manager's commission is a bit higher for the West Virginia associations than for associations in some other states. But the rate for the West Virginia associations does not appear to be too high in view of the fact that managers do all of the prorating and that most of the shipments are made up of small lots of several owners.

THE MANAGER

It is generally recognized that the quality of the management is of vital importance to the success of any cooperative association. Hibbard and co-authors state very clearly the value of good management *(5)*:

> "A good manager is necessary. His efficiency or inefficiency may result in the saving or loss to the association of an amount many times the salary he receives. Unless a man can be secured who has the necessary energy, ability, experience, and time to devote himself to the job, and unless that man has the intelligence to read and understand market reports, to advise the members of the association as to the best time to ship and to educate the members in business principles of marketing, the association will not last long. Livestock commission firms are almost of one accord in the belief that success or failure depends to the extent of 90 percent on a competent manager. When such a man is found he should be paid enough to make it worth his while to devote his attention to the position he holds . . . . . A competent manager will keep down the losses in transit due to deaths, cripples, and heavy shrinkages, and will earn his salary many times over.
>
> "There are advantages and disadvantages in hiring for manager a man who has been an independent shipper. No doubt he knows much about the business, but he will many times be distrusted by the members. Such men often have little faith in cooperation, and may have a motive in seeing it fail."

The problem of obtaining good management is a major one for West Virginia cooperative shipping associations. In each county are men well qualified to do the work if they were willing to undertake it. Several of the associations have been fortunate in procuring capable and sympathetic management; others have failed utterly. There are several reasons why it is difficult to secure good management in the state. The volume of business in all of the counties

is necessarily small. Even though the association marketed all the livestock, still the volume would not equal that of some of the local associations in Iowa, Minnesota, or several other states, where there is a great concentration of livestock. Up to the present, however, the limited volume has been still further limited decidedly by the competition of independent dealers through their methods of "tieing up" the livestock by contract, small loans, agreement to re-purchase livestock, etc. The small volume of business in sight is a handicap to securing good management. But in several counties, if a manager could market one-half or two-thirds of the livestock, he would have an income of from two to three thousand dollars for the marketing season.

A second reason why it is difficult to get capable management is that most of those who are capable are already trading on their own account and are not interested in cooperative marketing. There is a mania for trading in livestock in this state and it seems as though a large part of the better farmers are more or less engaged in it. Several associations have been unfortunate in their employment of managers who continued to buy and sell on their own account while managing the association. Some associations in the state undoubtedly owe their demise to this practice on the part of their manager.

The importance of good management to the success of shipping associations in West Virginia is well illustrated by the history of two of the county associations. From its organization until 1929 an association which may be designated as Association A was one of the strong ones in the state, ranking near the top in volume of business. The manager was capable, active, and interested in the work. At the end of the 1928 shipping season he moved from the state to enter other work. A new manager was selected for 1929. During that season the volume of business decreased to about three carloads. For 1930 another manager was selected, but no shipments were made.

When first organized, another group, designated here as Association B, was fortunate in obtaining a capable and interested manager. This man had been an independent dealer but became interested in cooperative shipping. He soon built up the association until it stood near the top of all associations in volume. Because of other interests he gave up the managership of the shipping association about 1926, when another manager was selected. This manager was sufficiently interested but lacked ability and was handicapped by poor health. The volume of business of this association rapidly decreased. Records were so poorly kept that it was impossible to include this association in the present study. At the end of the 1929 season this manager was released and the former manager again took over the affairs of the association in 1930. During that year the volume of business of the association increased until it was the largest in the state. There seems little doubt that the quality of management is the most important single factor in the success of cooperative shipping associations in West Virginia.

METHOD OF PRORATING EXPENSES

It is one of the duties of the manager to prorate the expenses of marketing. The expenses of each carload are prorated separately. The total expense is divided by the market weight and prorated to the patrons on the basis of hundredweight shipped. Some inequalities arise from this method, chief of which is the increase in marketing cost which a patron must pay if he happens to ship in a carload weighing less than the minimum. Mixed shipments, as indicated earlier, cause some small inequalities in marketing costs.

The Wirt county association has been using the "flat-rate" prorating method for the past few years. By this method one charge covers all expenses and there is no variation if a man ship either in a light or mixed car. Undoubtedly there is less injustice and less work in prorating by this method, but the difficult part is to establish the flat-rate which will just about cover the expenses for the shipping season.

LOSSES IN TRANSIT FROM DEATH AND CRIPPLES

It was not possible to summarize the amount of loss due to death and cripples because of the inadequacy of records which have been kept of such loss. The association pays the patron the appraised market value of the injured animals. These payments are made from the insurance fund.

The report *(3)* of a study of losses in shipping Ohio livestock contains certain conclusions which, because of the similarity of marketing conditions in the two states, appear to be at least partially applicable to West Virginia livestock shipping.

The study indicates that for sheep, single decks will show a higher loss for cripples and deads than will double decks. There was no outstanding difference between single decks and double decks in the cripple loss on calves, but with dead calves the loss in single decks was much higher.

In nine months of the year the number of dead sheep taken from cars was greater in partitioned than in unpartitioned cars. The loss was slightly higher for the unpartitioned cars during October, July, and August. Crippling was greater with sheep in partitioned cars for all months of the year except April and May, when the loss was about the same as in unpartitioned cars. With cattle and calves no outstanding differences in losses were found between partitioned and unpartitioned cars.

More sheep were crippled in mixed than in straight decks. The mixed single decks showed a much higher loss from crippled sheep than straight singles, while there was but little difference between straight and mixed double decks. The death rate of sheep showed that the losses were consistently much higher in mixed than in straight loads, and the single decks in practically all cars showed a larger difference in losses between straight and mixed loads than did the double decks.

The outstanding variations of losses by agencies shipping were for dead sheep and hogs. In both instances the cooperatives seemed to have a much higher loss at particular seasons of the year, i. e., December, January, February, March, June, and September, while the losses were about the same for both the cooperative and independent shipper during the other months.

Of course it may not be strictly accurate to take the above conclusions and apply them bodily to shipping under West Virginia conditions. As has been shown, much of the livestock was marketed by the West Virginia cooperative associations in single deck and mixed shipments. The Ohio study indicates that shipping in this way results in larger losses than by shipping in double deck and straight loads. Unfortunately, the data for West Virginia cooperative shipments are too meagre to shed any light on the subject, but the Ohio study gives reason to believe that the losses sustained by the associations were greater than they would have been in double deck and straight car shipments.

TABLE 28—*Average percentage shrink, total home weight, market weight, and years on which based, by cooperative association and kind of animals*

County	Years	Kind	Home weight	Market weight	Percentage shrink
Barbour	1928	Cattle	16,160	14,780	8.5
		Calves	23,765	21,875	8.0
		Lambs	18,490	16,955	8.3
Braxton	1927, '28, '29	Cattle	233,864	220,308	5.8
		Calves	45,456	43,020	5.4
		Lambs	461,950	410,616	11.1
Greenbrier	1923, '24, '25, '26, '27, '28, '29	Cattle	348,855	328,880	5.7
		Calves	1,365	1,330	2.6
		Lambs	353,762	313,554	11.4
Harrison	1925, '26, '27, '28, '29	Cattle	635,624	597,567	6.0
		Calves	2,187	2,052	6.2
		Lambs	300,075	263,703	12.1
Jackson	1929	Lambs	35,084	31,233	11.0
Nicholas	1928, '29	Lambs	122,136	106,058	13.2
Pocahontas	1926, '29	Cattle	79,559	73,120	8.1
		Calves	5,296	4,685	11.5
		Lambs	361,182	318,136	11.9
Roane	1925, '26, '27, '28, '29	Cattle	1,411,072	1,313,463	6.9
		Calves	55,931	50,925	9.0
		Lambs	204,388	180,122	11.9
Wirt	1925, '26, '27, '28, '29	Cattle	479,937	458,851	4.4
		Calves	368,931	353,717	4.1
		Lambs	321,261	303,136	5.6

SHRINKAGE

Shrinkage constitutes one of the major losses in shipping livestock. The average shrink for various kinds of animals and for various associations is shown in Table 28. It is beyond the scope of this study to investigate the causes of variations in shrinkage, and methods of keeping such at a minimum. The average shrinkage

shown in the table was determined from calculations based on the records of the various associations included in the study, and was calculated for use in the price comparisons which have been made.

VI. Independent Dealers' and Cooperative Prices Compared

PRELIMINARY CONSIDERATIONS

The amount of profit earned in relation to capital investment is the best measure of the efficiency of an independent business enterprise. This measure cannot be applied to a cooperative shipping association, since it is a non-profit organization. The purpose of a cooperative is to obtain not only for its patrons but also for all livestock farmers in the state the highest possible net returns on their livestock enterprises. Several factors contribute to the accomplishment of such a purpose: The association must seek to obtain the highest sales price possible for the quality of livestock it is marketing. To this end there must be a careful study of the different markets so as to put the animals on the particular market at the particular time when they will bring the highest price. Not only must the association seek to obtain the highest possible price; it must also do the marketing as cheaply as is possible in keeping with the service afforded. The association having the lowest marketing cost is not necessarily the most efficient one, because both the price received and the quality of the service rendered may be of a lower order. The association must seek to improve the quality of the livestock of the state, because an improvement in quality is a means of obtaining higher net returns. The association does not necessarily have to handle all the livestock to increase the net returns to the producers. It may force competitors to follow practices which will result in higher net returns to the producer.

It has not been possible to ascertain if the associations have always sold the livestock offered by patrons at the highest price possible to obtain for the given quality. So many factors are involved that, with limited data, analysis and proof are well nigh impossible. The quality of the animals figures largely in price, but quality cannot be accurately recorded. The supply of certain qualities offered on a market at a given time affects the price and only in a general way are such data recorded. The actual sale of livestock on the terminal market is made by an agent of the shipper rather than by the shipper himself. The terminal market price depends somewhat on the selling ability of the agent and is, therefore, partly beyond any control of the local shipper. The local shipper however does have something to do with the terminal price even though he does not do the actual selling. He selects the agent to sell for him and the wise choice of an agent may mean a consistently better price. Many of the cooperative associations in West Virginia sell through the Producers' Cooperative Commission Association in Pittsburgh, but freight differentials and market condi-

tions make it desirable for other of the associations to sell on the eastern markets. There are no cooperative commission associations on these markets and each association manager is left to select an independent commission firm to make his sales.

The local shipper has an opportunity to affect the terminal market price by selecting the time to put the livestock on the market, and to a more limited extent in the selection of the terminal market to which he ships. He also affects the terminal market price to a degree by having some influence on the condition in which the livestock arrives on the market.

There is reason to believe, however, that cooperative shipping associations in this state have not always received the highest price their livestock would have brought if marketed under different conditions. The manager is limited by small volume in his ability to ship animals to the proper market at the proper time. And the associations have not all been fortunate in obtaining the services of a manager competent to sell consistently near the top of the market for the quality offered. The first step toward changing these conditions is an increase in volume.

There is a fast-growing tendency in West Virginia to consider the function of a cooperative shipping association to be only to provide competition to an independent dealer. But competition means little unless the plane of competition is known. If the local competition can be raised to a high plane, the producer will receive greater returns than if the competition were on a lower plane. The plane of competition cannot be raised to the point where it should be until conditions are such that the cooperative sells its livestock at the highest possible price. Larger volume and better management, which is always hampered by small volume, are very important factors in raising this plane of competition.

In the analysis of the marketing costs of cooperative associations it has been shown that while costs are not excessive there is room to reduce them materially in most of the associations. Again a larger volume and better management are the key to reducing the marketing costs.

In some respects the cooperatives do not give their patrons as good service as the independent dealers. As a rule the dealer takes up the animals at the farm of the owner, while the patron of the shipping association must deliver his stock to the shipping point.

It has long been the custom in this state to drive livestock over the public roads to the shipping point. The development of hard-surfaced roads with the accompanying heavy motor traffic has made it dangerous, annoying, and in some sections practically impossible to move animals on foot to the shipping point. Few farmers are equipped with trucks, and to hire one means considerable expense. There appears to be an opportunity for cooperative associations to improve greatly the service, without a corresponding increase in cost, by trucking livestock from farm to shipping point.

In another respect the service of the cooperative is not so good as that given by the independent dealer, that is, in financing the livestock producer. As has been explained earlier, the dealer obtains a considerable part of his volume through his various livestock financing operations. Of course it is beyond the field of the cooperatives to make advances to producers as the dealers do, but the opportunities of financing livestock production offered through the Federal Farm Board have not yet been seized by the cooperatives.

The shipping associations in cooperation with the Agricultural Extension Division and the agricultural agents of the Baltimore and Ohio and the Chesapeake and Ohio Railroads have done much to improve the quality of livestock in West Virginia. This is especially true in the case of lambs. In 1926 these agencies began a lamb improvement campaign in the state looking toward the production of better quality market lamb. The campaign was first carried on in twenty of the better lamb-producing counties but since that time has been expanded to include 24 counties. From 1926 to 1930 approximately 21,000 lambs were docked and castrated at 923 different field meetings and demonstrations attended by 9,730 farmers. The campaigns also have emphasized the practice of treating for internal and external parasites, and this practice is fast becoming common. A large proportion of the lambs produced in the state are now docked and castrated, with the result that it has become common for West Virginia lambs to top the markets upon which they are sold. During the five years in which the cooperating agencies referred to above have operated the so-called "Purebred Ram Special", 914 purebred rams have been sold to farmers to head their flocks.

This improvement work was started around the cooperative shipping association. Because of the fact that it sold lambs on the basis of quality, the existence of the shipping associations has made an extension of this improvement possible. In earlier years it was customary for independent dealers to discourage the practice by making a price discrimination against docked and castrated lambs. Work toward the improvement of the quality of cattle has scarcely begun, but this provides a wide field of service for the cooperative associations and the agencies cooperating with them.

It has not been possible to compare the marketing costs of the cooperative associations with those of independent dealers, since a dealer's expenses are made up of numerous non-comparable items, and none could be found who pretended to keep any sort of adequate record of them. It has been possible, however, to make a fairly satisfactory comparison of the net price received by the patrons of cooperatives with prices paid by the independent dealers during 1928 and 1929.

Because of the varying quality of the animals and the varying times of sales, there are many pitfalls in a comparison of prices. Large numbers have been depended on to even up these variations to some extent. A personal knowledge of the conditions in the var-

ious counties permits the writer to say that there were no great variations in the quality of lambs or in the time of marketing between the independent dealers and the cooperative associations. There was, however, considerable difference in the quality of cattle marketed by the two agencies. A questionnaire sent to commission merchants who handled the livestock of both agencies, and to county agricultural agents who are familiar with the livestock in their counties, brought the uniform reply that, on the whole, the average quality of lambs marketed by the cooperative associations was somewhat higher than of those marketed by independent dealers, but that the average quality of the cattle marketed by the former was in most counties below that of the latter. Those cooperative associations which marketed cattle sold some of the best cattle in their respective counties, but such cattle did not form as large a proportion of their total marketings as was the case with many independent dealers.

In the early days of cooperative livestock marketing in West Virginia as well as in other states, farmers were induced to patronize the shipping association on the argument that they would receive a higher price for their animals than their neighbor, who sold to an independent dealer. The argument, which was probably true at that time, was that the independent dealer was selling on the same market as the cooperative, was taking a wider margin than the cost of marketing through the cooperative, and therefore could not pay the producer as much for his animals as he would receive by selling through the association.

Even yet farmers are prone to judge the association wholly on a comparison of prices. If the independent dealer pays as much or more than can be obtained through the cooperative, the verdict is that the cooperative has ceased to function effectively. This view loses sight of the fact that one of the most valuable accomplishments of a cooperative association is to be able to force competitors to pay as much as or more than could be received by selling through the association. When this is accomplished, not only do the patrons of the cooperative associations benefit by decreased marketing costs such as the associations afford, but all of those who sell to independent dealers profit also by their enforced reduction of margin.

It must not be forgotten that there are two ways in which total marketing cost may be reduced. In the first place the cooperative association may reduce it by operating on a non-profit basis, with actual cost at a minimum. In this case only those farmers who patronize the cooperative association receive the benefit. In the second place the cooperative association may offer such competition that the independent dealer is forced to pay as much as or more for the livestock than could be obtained by a producer by selling through the cooperative. In this case the patrons of the cooperative would retain their benefit, and in addition all the livestock producers would benefit from the reduced margins.

If the independent dealer continues to meet the competition of

the efficient cooperative he must either sell at a higher price, or take a minimum profit, or reduce marketing expenses, or do all of these. No matter which course he follows, the producer will receive a price equal to the cooperative price. Herein lies the importance of the cooperative association in continually raising the plane of competition. The producer who refuses to patronize the cooperative because he can secure as high or a little higher price by selling to an independent dealer should not lose sight of the fact that that price may be the result of the work of the cooperative. The battle continues to rage in West Virginia between the independent dealers and the cooperative associations, and independent dealers continue to use the effective weapon of paying some men more than their livestock is worth.

A comparison of the average prices received by patrons who marketed their livestock through cooperative associations, with average prices paid by the independent dealers, in 1928 and 1929, reveals the fact that in most counties the dealers paid higher average prices than those received through the associations. If we assume that the cost of marketing, as shown earlier, was not excessive, and that the quality of animals was much the same, this fact indicates that the cooperatives, for two years at least, have forced the independent dealers to meet their competition in prices and, possibly, to decrease their margin of profit.

METHODS EMPLOYED IN OBTAINING AND COMPARING PRICES

The value of animals sold through the cooperative associations is recorded on "prorating sheets" and on duplicate checks sent to the patron. The prorating sheets show the name of the patron, the number and kind of animals, home weight, market weight, and an itemized statement of all marketing expenses.

It was possible from these records to calculate the "home price" for animals marketed through the shipping association. Incomplete records made it necessary to omit from the calculations prices of some animals marketed by a few associations and prices of all the animals of two or three associations, but approximately 85 percent of all animals marketed by cooperatives during 1928 and 1929 were included in the calculations. The years chosen were favorable because 1928 was a period of rising livestock prices and 1929 a period of falling prices in the state.

Managers of the cooperatives have not been very diligent in observing the provisions of the by-laws, which authorize them to record the home weight of all animals, but the home weights for a goodly number of animals have been recorded by each association. From these it was possible to calculate an average shrink which could be used with reasonable accuracy in converting market weights to home weights for those animals whose home weights were not recorded. The shrinks thus arrived at are shown in Table 28.

A record of prices which independent dealers paid for livestock

was arrived at by the following method: Through a personal interview a schedule was filled out for 510 farmers in 11 counties. The following facts relative to livestock sold during 1928 and 1929 were obtained: (1) number of animals sold, by kinds; (2) home weight of anima'ls sold; (3) either price per cwt. or total value of each animal, whichever the farmer could remember.

Several independent dealers permitted the writer to transcribe from their records data concerning the weight and prices paid for animals which they had bought. Since these were the private records of the dealers, the accuracy of the prices and weights recorded is hardly open to question.

It was not possible to procure access to dealers' records in each county, but a comparison of average weights and prices obtained by means of the schedule with the average weights and prices procured from dealers' records in the same counties, indicates that the data obtained by the schedule are reasonably accurate. This comparison is shown in Table 29.

The close similarity of the results obtained by each method indicates that the records obtained by the schedule method in counties where dealers' records were not procured may also be considered reasonably accurate.

TABLE 29—*Comparison of records of weights and prices of livestock, as obtained from "scale records" of dealers and from a survey of farmers' sales, 1928 and 1929*

Source of records	Number of animals	Average weight (pounds)	Average price (per cwt.)
STEERS			
Farmers	9354	1109	$10.76
Dealers	5174	1105	10.89
CALVES			
Farmers	504	264	10.71
Dealers	97	197	7.52
COWS			
Farmers	384	991	7.45
Dealers	255	1005	7.81
HEIFERS			
Farmers	1862	840	9.25
Dealers	2060	855	10.06
LAMBS			
Farmers	16,397	76.8	11.12
Dealers	96,245	75.2	11.22

The largest difference between data obtained from the two sources, as shown in Table 29, is in the price of calves. This difference in reported price is due largely to the fact that farmers sold many of their calves as veals, either to local markets or hucksters, while the price procured from dealers' records was largely for calves too old for veal. From the two sources the records of the average weights and prices are very similar in the case of steers, heifers, cows, and lambs.

Records from farmers or independent dealers or from both were obtained in 12 counties. This number includes some counties in

which the strongest cooperative shipping associations were operating, some in which the associations were weak, and some where the association was not operating at all.

A comparison of the average home price which patrons of the cooperative association received for lambs weighing 60 pounds and above with the average price paid by independent dealers for lambs of the same weight is shown for 1928 in Table 30 and for 1929 in Table 31.

LAMB PRICES

In Table 30 the average weights and prices of 6,892 lambs (60 pounds and above) marketed through the various cooperative associations are compared with those of 50,831 lambs sold to independent dealers in 1928. The average weight of this group of lambs marketed by the cooperative association was 73.8 pounds (home weight), while for those sold to independent dealers it was 76.3 pounds. The farmers who sold these lambs through the cooperatives received an average farm price of $11.08 per cwt., while those selling to independent dealers received an average of $11.31 per cwt. During 1928 farmers who sold to independent dealers received on an average 23 cents per cwt. more than those who sold through the cooperatives, in spite of the fact that many reliable parties claim that the cooperatives marketed a larger percentage of higher quality lambs than did the independent dealer.

In Greenbrier county alone did the cooperative average price exceed that of the independent dealer. In Roane county, where the cooperative association was one of the most active in the state, the average price received from each agency was practically the same. It may be observed from Table 30 that there was little difference between the average price received in counties where cooperatives were operating and in those where they were not operating.

In Table 31 the average home weights and home prices of 7,823 lambs (60 pounds or over) marketed through cooperatives are compared with those of 58,291 lambs (60 pounds or over) sold to independent dealers in 1929. In that year, as in 1928, both the average price and weight of the lambs marketed through the cooperatives were below those of the lambs sold to independent dealers. The average weight was only slightly below, but the average price was $1.17 per cwt. below the average price paid by the independent dealers. The average price for lambs in counties where cooperatives were not operating again compares favorably with the average price in counties which had active associations.

In 1929, as in 1928, the average price of the cooperative was higher than the price paid by dealers only in Greenbrier county. Two reasons may account for this. The Greenbrier association not only had lower costs than the associations in other counties but it is claimed by some people familiar with the situation that this association marketed a much larger percentage of top lambs than did the

TABLE 30—*Number of lambs weighing* sixty pounds and above, total weight, average weight, average price† per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1928*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	218	536	16,821	46,143	77.2	86.1	$11.039	$11.693	$ 1,856.88	$ 5,395.65
Braxton	2,632	1,341	195,150	97,231	74.1	72.5	10.899	11.609	21,270.14	.....
Greenbrier	1,426	13,775	107,530	1,055,267	75.4	76.6	11.844	10.976	12,735.85	115,831.36
Harrison	606	120	45,081	9,370	74.4	78.1	11.424	11.720	5,150.13	1,098.15
Jackson	....	497	.....	37,913	...	76.3	.....	10.848	.....	4,112.69
Lewis	....	2,775	.....	214,562	...	77.3	.....	11.821	.....	25,362.91
Monroe	....	3,257	.....	251,117	...	77.2	.....	12.077	.....	30,328.20
Nicholas	489	.....	36,439	.....	74.5	...	9.787	.....	3,566.27	.....
Pocahontas	....	24,968	.....	1,901,434	...	76.2	.....	11.332	.....	215,476.29
Randolph	....	1,207	.....	89,602	...	74.2	.....	11.328	.....	10,150.18
Ritchie	....	949	.....	66,096	...	69.6	.....	11.102	.....	7,338.05
Roane	769	558	55,126	41,506	71.7	74.4	10.956	11.098	6,039.47	4,606.26
Upshur	....	848	.....	69,151	...	81.5	.....	11.685	.....	8,080.13
Wirt	752	.....	52,644	.....	70.0	...	10.933	.....	.....	.....
Total	6,892	50,831	508,791	3,879,392	73.8	76.3	$11.080	$11.318	$56,374.46	$439,077.66

*Home weight. †Home price.

TABLE 31—*Number of lambs weighing[1] sixty pounds and above, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1929*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	351	519	28,223	42,887	80.4	82.6	$ 9.662	$11.455	$ 2,728.11	$ 4,911.64
Braxton	346	1,382	25,640	98,657	74.1	71.4	9.465	10.833	2,426.83	10,687.48
Doddridge	233	....	15,862	.....	68.1	...	10.470	.....	1,660.78	.....
Greenbrier	1025	14,285	81,631	1,047,211	79.6	73.3	11.506	11.238	9,361.76	117,681.46
Harrison	702	174	50,050	13,340	71.3	76.7	10.873	11.279	5,441.96	1,504.65
Jackson	506	689	36,364	51,127	71.9	74.2	10.193	10.721	3,706.63	5,481.12
Lewis	....	12,659	.....	963,820	...	76.1	.....	11.589	.....	110,919.92
Monroe	....	1,442	.....	106,295	...	73.7	.....	11.891	.....	12,639.17
Nicholas	962	....	70,382	.....	73.2	...	9.508	.....	6,692.08	.....
Pocahontas	1895	21,737	145,120	1,705,215	76.6	78.4	9.610	11.202	13,945.47	191,015.80
Randolph	....	1,583	.....	124,465	...	78.6	.....	10.740	.....	13,367.73
Ritchie	....	1,042	.....	71,075	...	68.2	.....	10.666	.....	7,581.12
Roane	925	1,762	67,480	125,249	73.0	71.1	9.584	9.853	6,467.14	12,341.31
Upshur	....	1,017	.....	82,874	...	81.5	.....	11.689	.....	9,687.29
Wirt	878	....	62,740	.....	71.5	...	10.065	.....	6,314.50	.....
Total	7823	58,291	583,492	4,432,205	74.6	76.0	$10.068	$11.231	$58,745.26	$497,818.69

[1]Home weight. [2]Home price.

other associations, in comparison with the percentage of top lambs marketed by the independent dealers in the corresponding counties.

During these years the manager of the Greenbrier association was not very active, shipping mostly only the animals of some of the better producers in the county. This lack of aggressive competition on the part of the manager may be an additional reason for the difference in prices. Patrons of the Greenbrier cooperative however received an average of 49 cents per cwt. less than dealers paid in Monroe, a neighboring county, where the cooperative was not active, but where the lambs are of a somewhat higher quality and where there was unusual competition between independent dealers.

Tables 32 and 33 show a comparison of the average home prices for lambs weighing less than 60 pounds, home weight, marketed through cooperatives, with the average home prices for the same weight-class of lambs paid by independent dealers in 1928 and 1929, respectively.

For 1928 the comparison is between 1,435 lambs weighing less than 60 pounds marketed through cooperatives, and 1,223 lambs sold to private dealers. The average weight of these two groups was the same, but the average home price paid by independent dealers was 62 cents per cwt. above the price received through the cooperative. In Roane county alone was the cooperative price higher than the independent dealer price, but the numbers involved are two small for a dependable comparison.

In 1929 the average home price of 1,290 lambs weighing less than 60 pounds, sold through the associations, was 61 cents per cwt. below the average home price of 2,297 lambs of the same weight-class sold to independent dealers. These data lend weight to the contention that independent dealers do not give great consideration to quality when buying lambs.

CATTLE PRICES

1. Steers

Table 34 shows a comparison of the average weight and price of 771 steers marketed through the cooperative associations during 1928 with those of 7,058 steers sold to independent dealers.

The average weight of the steers marketed through the associations was 1,117 pounds, while of those sold to independent dealers it was 1,091. The average home price received for the steers marketed through cooperatives was $11.17 per cwt., or $0.50 per cwt. more than the $10.67 for those sold to independent dealers. Not all of the latter group went to market, but all those sold through the shipping associations went to a terminal market, except a few which were sold to Ohio cooperative shipping associations to be distributed to their patrons for feeder-stock.

It may be observed from the table that in only one county, Greenbrier, was the shipping association price higher than the price paid by independent dealers; the average weight was also greater.

TABLE 32—*Number of lambs weighing[1] less than sixty pounds, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1928*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	5	....	259	.....	51.8	...	$7.981	$	$ 20.67	$ .....
Braxton	676	128	35,894	6,471	53.1	50.6	6.453	6.916	2316.36	447.56
Greenbrier	....	576	.....	33,446	...	58.1	.....	8.140	.....	2722.63
Harrison	114	10	6,367	550	55.9	55.0	8.199	10.00	522.01	55.00
Jackson	....	3	.....	165	...	55.0	.....	8.00	.....	13.20
Lewis	....	109	.....	5,291	...	48.5	6.000	.....	.....	317.48
Monroe	....	4	.....	122	...	30.5	.....	10.00	.....	12.20
Nicholas	116	....	6,189	.....	53.4	...	6.913	.....	427.86	.....
Pocahontas	....	348	.....	17,567	...	50.5	.....	8.232	.....	1446.05
Randolph	....	3	.....	150	...	50.0	.....	5.00	.....	7.50
Ritchie	....	32	.....	1,395	...	43.6	.....	5.888	.....	82.15
Roane	269	10	14,365	500	53.4	50.0	8,145	7.000	1170.00	35.00
Wirt	255	....	13,993	.....	54.9	...	7.801	.....	1091.64	.....
Total	1435	1223	77,067	65,657	53.7	53.7	$7.200	$ 7.827	$5548.54	$5138.77

[1]Home weight. [2]Home price.

TABLE 33—*Number of lambs weighing[1] less than sixty pounds, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1929*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	52	....	2,870	.....	55.2	...	$ 5.284	$	$ 180.35	$ .....
Braxton	103	117	5,555	6,208	43.9	53.1	6.000	6.501	333.33	403.61
Doddridge	27	....	1,473	.....	54.6	...	6.420	....	94.57	.....
Greenbrier	....	303	.....	16,556	...	54.6	.....	8.012	.....	1326.30
Harrison	84	4	3,987	232	47.5	58.0	11.461	9.000	456.94	20.88
Jackson	182	17	10,187	849	56.0	49.9	7.721	7.382	786.51	62.67
Lewis	....	851	.....	42,800	...	50.3	....	10.590	.....	4532.61
Monroe	....	130	.....	7,631	...	58.7	....	6.532	.....	498.44
Nicholas	154	....	8,026	.....	52.1	...	8.421	....	675.89	.....
Pocahontas	58	549	3,115	27,885	53.7	50.8	5.743	6.958	178.90	1940.15
Ritchie	....	96	.....	4,743	...	49.4	....	7.134	.....	338.35
Roane	336	216	17,576	10,743	52.3	49.7	7.697	6.676	1352.87	717.18
Upshur	....	14	.....	732	...	52.3	....	8.705	.....	63.72
Wirt	294	....	15,682	.....	53.3	...	7.980	....	1251.37	.....
Total	1290	2297	68,471	118,379	53.9	51.5	$ 7.756	$ 8.366	$5310.63	$9903.91

[1]Home weight. [2]Home price.

The Greenbrier association handled some of the best cattle in the county and a smaller proportion of light cattle and cattle of low grade than any other of the associations. The associations in Roane and Harrison counties handled lighter cattle and a larger proportion of feeder cattle than were handled by independent dealers.

A comparison of the average weight and home price of 714 steers marketed by the cooperative associations in 1929 is made in Table 35 with those of 7,470 steers sold to independent dealers.

The average weight of the steers marketed through the association in 1929 was 1,047 pounds and that of steers sold to independent dealers was 1,123 pounds, just the reverse of the situation in 1928. The average price received from sales through the association was $9.53, while the steers sold to the independent dealers brought an average price of $10.93 per cwt. In no county was either the average weight or price as great for the steers sold through the associations as for those sold to independent dealers.

A more significant comparison of prices may be obtained by comparing the prices of animals in the same weight groups. Weight is one of the factors in price determination, but is not the only one and probably not the most important one. However, it was the only tangible factor available on which a comparison could be made. From replies to a questionnaire sent to commission merchants and county agricultural agents it appears as though the cattle handled by dealers in West Virginia, on an average, have been somewhat higher in quality than those handled by cooperative shipping associations. This is just the reverse of the situation respecting the quality of lambs. With quality a somewhat uncertain factor, this price comparison lacks exactitude, but may give some indication of the situation, if the prices for animals in the same weight groups are used.

Tables 36 and 37 show a comparison, by counties, of the average home weights and prices of steers weighing from 550 to 899 pounds marketed through cooperatives in 1928 and 1929, respectively, with those of steers of the same weight groups sold to independent dealers.

The comparison for 1928 is for 126 steers (550 to 899 pounds) marketed through cooperatives with 1,122 steers of the same weight class sold to independent dealers. The steers marketed through the cooperatives averaged 47 pounds heavier than those sold to private dealers, but the price per cwt. was 79 cents less. In only one county, Harrison, was the cooperative price higher than the independent dealer price. The numbers compared for this county are too small, however, to be of much significance.

The comparison for 1929 was between 168 steers (550 to 899 pounds) marketed cooperatively and 1,040 sold to private dealers. The average weight was practically identical for both groups, but the price paid by independent dealers was $1.26 per cwt. more than the price received through cooperatives.

TABLE 34—*Number of steers, all weights[1] combined, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1928*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	6	365	4,111	403,232	685.1	1104.7	$ 6.660	$11.323	$ 273.78	$ 45,659.79
Braxton	2	474	1,700	514,882	850.0	1086.2	8.486	9.917	144.26	51,062.62
Greenbrier	338	1129	433,584	1,354,153	1282.8	1139.4	12.440	10.784	53,936.79	146,036.76
Harrison	97	277	106,926	351,180	1102.3	1267.8	9.995	10.757	10,687.09	37,778.00
Jackson	...	1127	.....	1,311,578	.....	1163.8	.....	11.092	.....	145,480.14
Lewis	...	1296	.....	1,257,933	.....	970.6	.....	10.622	.....	133,613.06
Monroe	...	397	.....	494,594	.....	1245.8	.....	11.046	.....	54,633.15
Pocahontas	...	204	.....	174,400	.....	854.9	.....	8.532	.....	14,880.00
Randolph	...	462	.....	419,915	.....	908.9	.....	10.262	.....	43,094.10
Ritchie	...	272	.....	275,743	.....	1013.8	.....	10.019	.....	27,627.98
Roane	312	604	298,443	684,448	956.5	1133.2	9.932	10.521	29,641.94	72,001.57
Upshur	...	451	.....	460,350	.....	1020.7	.....	10.870	.....	50,038.77
Wirt	16	....	16,613	.....	1038.3	.....	9.504	.....	1,578.94	.....
Total	771	7058	861,377	7,702,408	1117.2	1091.3	$11.175	$10.671	$96,262.80	$821,915.94

[1]Home weight. [2]Home price.

TABLE 35—*Number of steers, all weights[1] combined, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1929*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	1	561	454	683,381	454.0	1281.1	$10.170	$11.553	$ 46.17	$ 78,949.80
Braxton	...	456	.....	491,574	.....	1078.0	.....	10.577	.....	51,994.33
Doddridge	18	...	18,204	.....	1011.3	.....	8.634	.....	1,571.68	.....
Greenbrier	183	579	213,927	684,497	1169.0	1182.2	10.745	11.046	22,987.14	75,612.06
Harrison	...	270	.....	347,475	.....	1286.9	.....	11.687	.....	40,607.92
Jackson	17	1138	17,354	1,313,922	1020.8	1154.6	8.825	10.918	1,531.56	143,459.89
Lewis	...	730	.....	802,910	.....	1099.9	.....	10.883	.....	87,381.56
Monroe	...	975	.....	1,151,716	.....	1181.2	.....	11.744	.....	135,236.83
Pocahontas	17	558	14,592	584,970	858.4	1048.3	7.901	10.768	1,152.90	62,992.20
Randolph	...	455	.....	440,212	.....	967.5	.....	10.058	.....	44,275.57
Ritchie	...	341	.....	361,230	.....	1059.3	.....	9.626	.....	34,772.55
Roane	430	753	440,464	824,230	1024.3	1094.6	9.247	10.391	40,730.49	85,642.96
Upshur	...	654	.....	704,823	.....	1077.7	.....	10.775	.....	75,942.85
Wirt	48	...	42,646	.....	888.5	.....	7.590	.....	3,236.82	.....
Total	714	7470	747,641	8,390,942	1047.1	1123.3	$ 9.531	$10.930	$71,256.76	$917,158.52

[1]Home weight. [2]Home price.

TABLE 36—*Number of steers weighing[1] from 550 to 899 pounds, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1928*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	6	36	4,111	30,600	685.1	850.0	$6.660	$10.250	$ 273.78	$ 3,136.50
Braxton	1	28	800	23,305	800.0	832.3	7.570	9.374	60.56	2,184.54
Greenbrier	...	66	.....	46,669	....	707.1	.....	10.782	.....	5,031.90
Harrison	11	3	8,035	2,100	730.5	700.0	7.317	6.000	587.90	126.00
Jackson	...	17	.....	12,389	....	728.8	.....	9.295	.....	1,151.50
Lewis	...	525	.....	401,172	....	764.1	.....	10.259	.....	41,155.53
Monroe	...	10	.....	7,136	....	713.6	.....	10.843	.....	773.75
Pocahontas	...	96	.....	64,500	....	671.9	.....	6.124	.....	3,950.00
Randolph	...	140	.....	91,180	....	651.3	.....	10.577	.....	9,643.75
Ritchie	...	66	.....	46,838	....	709.7	.....	9.330	.....	4,370.00
Roane	108	45	85,155	36,050	788.5	801.1	9.530	10.659	8115.30	3,842.50
Upshur	...	90	.....	58,760	....	652.9	.....	10.328	.....	6,068.65
Total	126	1122	98,101	820,699	778.6	731.5	$9.212	$ 9.923	$9037.54	$81,434.62

[1]Home weight. [2]Home price.

TABLE 37—*Number of steers weighing[1] from 550 to 899 pounds, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1929*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	...	18	.....	12,007	....	856.1	$	$10.717	$.....	$ 1,286.85
Braxton	...	83	.....	68,760	....	828.4	.....	9.613	.....	6,609.99
Doddridge	9	....	7,139	.....	793.2	....	7.700	.....	549.70	.....
Greenbrier	12	84	7,858	65,108	654.8	775.1	8.539	9.281	671.02	6,042.40
Harrison	...	1	.....	770	....	770.0	.....	6.000	.....	46.20
Jackson	1	73	677	49,069	677.0	672.2	7.170	11.313	48.54	5,551.21
Lewis	...	50	.....	35,895	....	717.7	.....	10.080	.....	3,618.30
Monroe	...	108	.....	85,480	....	791.5	.....	10.129	.....	8,658.20
Pocahontas	6	161	4,322	112,500	720.3	698.8	6.449	7.813	278.73	8,790.00
Randolph	...	150	.....	121,975	....	813.2	.....	9.629	.....	11,744.50
Ritchie	...	88	.....	62,387	....	708.9	.....	9.600	.....	5,986.50
Roane	116	96	86,556	67,752	748.8	705.8	8.739	10.298	7,590.41	6,977.38
Upshur	...	128	.....	92,427	....	722.1	.....	9.867	.....	9,120.20
Wirt	24	....	18,727	.....	780.2	....	7.200	.....	1,348.33	.....
Total	168	1040	125,579	774,130	747.5	744.4	$8.351	$ 9.615	$10,486.73	$81,434.62

[1]Home weight. [2]Home price.

The independent dealers do not ship a large number of steers in this weight class, but rather distribute them to other farmers in the state for further grazing. If the trend of cattle prices appears to be upward, the independent dealer can afford to pay a higher price for steers of this class to handle in this way than if they were put in the market for slaughter.

Tables 38 and 39 show a comparison, by counties, of the average home weight and price of steers weighing from 900 to 1099 pounds which were marketed through the cooperatives in 1928 and 1929, respectively, with those of steers sold to independent dealers during the same years.

For 1928 the comparison was between 195 steers (900 to 1099 pounds) marketed through the cooperatives and 1,525 sold to independent dealers. The average weight of the two groups was practically the same. The average price received from sales to independent dealers was 20 cents per cwt. more than the price received from sales through cooperatives. In only one county, Roane, was the cooperative price higher than the independent dealer price. The numbers for Greenbrier county are too small for comparison. Forty-six percent of the steers sold through the Roane association in 1928 fell in this weight group. The average price for the cooperative in Roane county was $1.64 above the price paid by dealers for this weight-class of steers. But the dealer price was higher in most of the other counties.

During 1928 the Roane association selected and sold most of its good stock cattle to an Ohio cooperative. The cattle were selected with care and hence a premium price was received. This circumstance, in part, may explain why the cooperative price was considerably above the independent dealer price during this year.

For 1929 the comparison was between 212 steers (900 to 1099 pounds) marketed through the cooperatives and 1,265 sold to independent dealers. The average weight of the steers sold through cooperatives was somewhat greater, but the average price was 98 cents per cwt. lower than the price paid by independent dealers. In no county was the average price received through cooperative sales as much as that received from sales to independent buyers.

Tables 40 and 41 show a comparison, by counties, of the average weight and price of steers weighing from 1,100 to 1,299 pounds which were marketed through the cooperatives in 1928 and 1929, respectively, with those of steers sold to independent dealers.

For 1928 the comparison was between 286 steers (1100 to 1299 pounds) sold through the cooperatives and 3,264 sold to independent dealers. The average weight of the steers sold through the cooperatives was somewhat greater than of those sold to independent dealers and the average price was 67 cents per cwt. more. The average price for cooperative sales was increased by the exceptionally favorable showing which the Greenbrier county association made. In only one other county, however, was the cooperative price higher than the dealer price.

TABLE 38—*Number of steers weighing[1] 900 to 1099 pounds, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1928*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	...	122	.....	118,262	....	969.4	$	$10.474	$.....	$ 12,386.94
Braxton	1	262	900	267,372	900.0	1020.5	9.300	9.341	83.70	24,974.02
Greenbrier	1	84	1,039	80,093	1039.0	953.5	15.410	10.625	160.11	8,509.96
Harrison	39	....	38,888	.....	997.1	....	9.293	.....	3,613.26	.....
Jackson	...	139	.....	133,277	....	958.8	.....	10.040	.....	13,381.36
Lewis	...	256	.....	251,736	....	983.3	.....	10.150	.....	25,551.38
Monroe	...	3	.....	3,000	....	1000.0	.....	10.000	.....	300.00
Pocahontas	...	107	.....	109,400	....	1022.4	.....	9.936	.....	10,870.00
Randolph	...	140	.....	131,985	....	942.5	.....	10.016	.....	13,219.15
Ritchie	...	108	.....	106,023	....	981.7	.....	11.182	.....	11,854.98
Roane	145	113	142,903	108,008	985.5	955.8	9.949	8.303	14,218.09	8,968.17
Upshur	...	191	.....	195,050	....	1021.2	.....	10.498	.....	20,476.20
Wirt	9	....	8,825	.....	980.5	....	8.961	.....	790.79	.....
Total	195	1525	192,555	1,504,206	987.5	986.4	$ 9.798	$10.005	$18,865.95	$150,492.16

[1]Home weight. [2]Home price.

TABLE 39—*Number of steers weighing[1] 900 to 1099 pounds, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1929*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	...	28	.....	28,440	.....	1015.7	$	$ 9.719	$.....	$ 2,764.20
Braxton	...	119	.....	118,475	.....	995.6	.....	9.662	.....	11,447.01
Doddridge	1	....	1,000	.....	1000.0	....	7.700	.....	770.00	.....
Greenbrier	43	123	45,243	121,937	1052.2	991.4	10.201	10.452	4,615.32	12,744.47
Jackson	10	53	9,505	50,200	950.5	947.2	8.260	8.462	785.14	4,248.25
Lewis	...	218	.....	209,475	.....	960.9	.....	10.326	.....	21,629.57
Monroe	...	149	.....	148,349	.....	995.6	.....	10.288	.....	15,261.80
Pocahontas	11	169	10,270	175,190	933.6	1036.6	8.512	10.576	874.17	18,528.40
Randolph	...	101	.....	99,090	.....	981.1	.....	9.966	.....	9,875.45
Ritchie	...	58	.....	51,094	.....	880.9	.....	9.855	.....	5,035.44
Roane	130	146	131,640	139,523	1012.6	955.6	9.371	11.031	12,335.46	15,391.42
Upshur	...	101	.....	98,380	.....	974.1	10.00	10.921	.....	10,744.05
Wirt	17	....	16,355	.....	962.1	....	7.628	.....	1,247.62	.....
Total	212	1265	214,013	1,240,153	1009.5	980.5	$ 9.315	$10.295	$19,934.71	$127,670.06

[1]Home weight. [2]Home price.

TABLE 40—*Number of steers weighing*[1] *1100 to 1299 pounds, total weight, average weight, average price*[2] *per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1928*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	...	113	.....	131,250	.....	1161.5	$	$11.063	$.....	$ 14,520.75
Braxton	...	157	.....	187,800	.....	1196.2	.....	10.790	.....	20,263.56
Greenbrier	199	540	245,047	659,761	1231.4	1221.8	12.050	10.915	29,528.84	72,011.58
Harrison	29	71	34,310	85,180	1217.6	1199.7	11.032	10.077	3,895.54	8,584.00
Jackson	...	946	.....	1,133,338	.....	1198.1	.....	11.224	.....	127,212.27
Lewis	...	446	.....	523,885	.....	1174.6	.....	11.021	.....	57,738.80
Monroe	...	324	.....	401,498	.....	1239.2	.....	10.794	.....	43,337.13
Randolph	...	157	.....	185,800	.....	1183.4	.....	10.302	.....	19,141.20
Ritchie	...	43	.....	51,182	.....	1190.3	.....	10.845	.....	5,550.50
Roane	51	366	59,638	431,390	1169.4	1178.7	10.223	10.637	6,096.93	45,885.90
Upshur	...	101	.....	119,725	.....	1185.4	.....	10.956	.....	13,117.12
Wirt	7	....	7,788	.....	1113.0	.....	10.120	.....	788.15	.....
Total	286	3264	347,783	3,910,859	1216.0	1198.2	$11.590	$10.928	$40,309.46	$427,362.81

[1]Home weight. [2]Home price.

TABLE 41—*Number of steers weighing*[1] *from 1100 to 1299 pounds, total weight, average weight, average price*[2] *per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1929*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	...	213	.....	252,194	.....	1184.0	$	$10.511	$.....	$ 26,507.50
Braxton	...	254	.....	304,339	.....	1198.3	.....	11.151	.....	33,937.33
Doddridge	6	....	7,441	.....	1240.2	.....	9.000	.....	669.72	.....
Greenbrier	101	135	122,225	171,047	1210.1	1267.0	10.827	10.979	13,232.76	18,779.53
Harrison	...	77	.....	91,920	.....	1193.8	.....	11.311	.....	10,396.80
Jackson	6	855	7,172	1,000,753	1195.0	1170.5	9.730	10.804	697.84	108,125.43
Lewis	...	356	.....	417,805	.....	1173.6	.....	11.326	.....	47,320.39
Monroe	...	287	.....	344,165	.....	1199.2	.....	11.579	.....	39,849.91
Pocahontas	...	105	.....	128,990	.....	1228.5	.....	12.000	.....	15,478.80
Randolph	...	173	.....	203,749	.....	1177.7	.....	10.364	.....	21,115.62
Ritchie	...	90	.....	109,140	.....	1212.7	.....	10.146	.....	11,072.81
Roane	164	367	193,750	423,855	1181.4	1154.9	9.523	9.900	18,449.94	41,963.66
Upshur	...	216	.....	257,340	.....	1191.4	.....	10.865	.....	27,958.80
Wirt	6	....	7,073	.....	1179.0	.....	8.670	.....	613.23	.....
Total	283	3128	337,661	3,705,297	1193.1	1184.6	$ 9.970	$10.863	$33,663.49	$402,506.58

[1]Home weight. [2]Home price.

For 1929 the comparison was between 283 steers (1100 to 1299 pounds) sold through the cooperatives and 3,128 steers sold to independent dealers. The average weight of the steers sold through the cooperative was again somewhat greater, but the average price was 89 cents per cwt. lower than of those steers sold to independent dealers.

Tables 42 and 43 show the average weight and price of steers weighing from 1300 to 1499 pounds marketed by the cooperatives in 1928 and 1929, respectively, compared with those of steers of the same weight-class sold to independent dealers. In Greenbrier county alone are the numbers large enough to make any adequate comparison. In 1928 patrons of the cooperative in this county received a higher average price for steers in this weight group than the price paid by independent dealers, but in 1929 independent dealers paid the higher average price.

Tables showing the average weight and prices of steers weighing 1500 pounds and over and of steers weighing from 250 to 549 pounds were prepared. Because of the small number of such animals marketed by the cooperatives, no valid comparison of prices could be made. The animals of these weight groups however were included in the summary Tables 34 and 35.

2. Heifers

Tables 44 and 45 show the average home weight and price received for heifers sold through the cooperative associations compared with those of heifers sold to independent dealers during 1928 and 1929, respectively.

In 1928 the average home price received for heifers marketed through the cooperative was 15 cents per cwt. above the price paid by independent dealers. The Roane county association handled a large majority of the heifers sold by cooperatives during this year. The price received by patrons of this association was 19 cents per cwt. above the independent dealer price in that county. In 1929, however, the independent dealers' average price was $1.59 per cwt. above the association price. In the Roane association the price was also well below the independent dealer price in that year.

Tables 46 to 51 show a comparison of average prices of the heifers when divided into various weight classes. It may be observed that the price paid by independent dealers was consistently above the price received through the cooperatives in each weight class during both years, except that of the 850 to 1,049 pound class in 1928. It was in this year that the Roane county association sold stock cattle to the Ohio cooperative.

3. Calves

Tables 52 and 53 show the average home price of calves weighing less than 250 pounds, received through the cooperatives, compared with that of calves sold to independent dealers in 1928 and 1929, respectively.

TABLE 42—*Number of steers weighing[1] from 1300 to 1499 pounds, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1928*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	...	94	.....	123,120	.....	1309.8	$	$12.683	$.....	$ 15,615.60
Braxton	...	27	.....	36,405	.....	1348.3	.....	10.000	.....	3,640.50
Greenbrier	138	350	187,498	466,970	1358.7	1334.2	12.932	10.697	24,247.84	49,952.32
Harrison	16	203	21,671	263,900	1354.4	1300.0	10.660	11.015	2,310.10	.....
Jackson	...	22	.....	31,174	.....	1417.0	.....	11.500	.....	3,585.01
Lewis	...	56	.....	74,245	.....	1325.8	.....	11.419	.....	8,477.85
Monroe	...	60	.....	82,960	.....	1382.7	.....	12.322	.....	10,222.27
Ritchie	...	55	.....	71,700	.....	1303.6	.....	8.162	.....	5,852.50
Roane	8	80	10,747	109,000	1343.4	1362.5	11.274	12.216	1,211.62	13,315.00
Upshur	...	59	.....	79,115	.....	1340.9	.....	11.852	.....	9,376.80
Total	162	1006	219,916	1,338,589	1357.5	1330.6	$12.627	$11.139	$27,769.56	$149,105.85

[1]Home weight. [2]Home price.

TABLE 43—*Number of steers weighing[1] 1300 to 1499 pounds, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1929*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	..	264	.....	353,740	.....	1339.9	$	$12.392	$	$ 43,836.25
Doddridge	2	....	2,624	.....	1312.0	.....	10.490	.....	275.26	.....
Greenbrier	27	231	38,601	323,405	1429.7	1400.0	11.575	11.666	4468.04	37,729.66
Harrison	..	175	.....	227,500	.....	1300.0	.....	12.000	.....	27,300.00
Jackson	..	155	.....	212,900	.....	1373.5	.....	11.938	.....	25,415.00
Lewis	..	106	.....	139,735	.....	1318.3	.....	10.601	.....	14,813.30
Monroe	..	429	.....	572,762	.....	1335.1	.....	12.460	.....	71,366.12
Pocahontas	..	123	.....	168,290	.....	1368.2	.....	12.000	.....	20,195.00
Ritchie	..	91	.....	126,709	.....	1392.4	.....	9.129	.....	11,567.80
Roane	20	142	28,218	192,100	1410.9	1352.8	8.345	11.041	2354.68	21,210.50
Upshur	..	179	.....	242,926	.....	1357.1	.....	10.907	.....	26,495.80
Total	49	1895	69,443	2,560,067	1417.2	1351.0	$10.221	$11.716	$7097.98	$299,929.43

[1]Home weight. [2]Home price.

TABLE 44—*Number of heifers, all weights[1] combined, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1928*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	9	68	6,513	61,830	723.7	909.3	$ 6.519	$10.209	$ 424.60	$ 6,312.45
Braxton	35	6	29,121	5,345	832.0	890.8	10.047	10.000	2,925.80	534.50
Greenbrier	...	57	.....	47,986	....	841.9	.....	9.303	.....	4,464.03
Harrison	...	20	.....	16,000	....	800.0	.....	11.000	.....	1,760.00
Jackson	...	41	.....	34,450	....	840.2	.....	9.492	.....	3,270.00
Lewis	...	931	.....	782,746	....	840.8	.....	9.580	.....	74,984.71
Monroe	...	60	.....	53,329	....	888.8	.....	10.017	.....	5,342.05
Pocahontas	...	11	.....	8,400	....	763.6	.....	9.107	.....	765.00
Randolph	...	69	.....	51,530	....	746.8	.....	9.371	.....	4,828.88
Ritchie	...	56	.....	46,068	....	822.6	.....	9.086	.....	4,185.95
Roane	234	141	184,398	123,028	788.0	872.5	9.709	9.517	17,902.59	11,708.43
Upshur	...	253	.....	207,120	....	818.7	.....	8.554	.....	17,716.01
Wirt	6	....	4,850	.....	808.3	....	6.981	.....	338.59	.....
Total	284	1713	224,882	1,437,832	791.8	839.4	$ 9.601	$ 9.450	$21,591.58	$135,872.01

[1]Home weight. [2]Home price.

TABLE 45—*Number of heifers, all weights[1] combined, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1929*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	1	128	886	116,185	886.0	907.7	$7.230	$ 9.390	$ 64.06	$ 10,909.90
Braxton	...	3	.....	2,915	....	971.7	.....	8.836	.....	257.57
Doddridge	21	....	19,246	.....	916.5	....	7.653	.....	1,472.88	.....
Greenbrier	49	93	44,239	80,779	902.8	868.6	9.501	9.659	4,203.33	7,802.64
Harrison	...	41	.....	34,930	....	852.0	.....	9.523	.....	3,326.40
Jackson	...	134	.....	113,915	....	850.1	.....	9.248	.....	10,534.36
Lewis	...	895	.....	779,812	....	871.3	.....	10.620	.....	82,813.96
Monroe	...	40	.....	37,280	....	932.0	.....	10.026	.....	3,737.63
Pocahontas	2	138	1,820	96,200	910.0	697.1	8.826	7.474	160.63	7,190.00
Randolph	...	90	.....	80,350	....	892.8	.....	10.130	.....	8,139.62
Ritchie	...	90	.....	70,986	....	988.7	.....	9.101	.....	6,460.12
Roane	193	315	138,544	273,572	717.8	868.5	8.058	9.532	11,163.71	26,077.01
Upshur	...	242	.....	199,615	....	824.9	.....	9.353	.....	18,670.91
Wirt	13	....	9,754	.....	750.3	....	6.685	.....	652.08	.....
Total	279	2209	214,489	1,886,539	768.8	854.0	$8.260	$ 9.856	$17,716.69	$185,920.12

[1]Home weight. [2]Home price.

TABLE 46—*Number of heifers weighing[1] from 550 to 849 pounds, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1928*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	7	...	4,507	.....	643.9	....	$ 6.528	$	$ 294.21	$ .....
Braxton	10	2	7,471	1,675	747.1	837.5	10.672	10.000	797.34	167.50
Greenbrier	...	10	.....	7,500	....	750.0	.....	7.921	.....	594.05
Harrison	...	20	.....	16,000	....	800.0	.....	11.000	.....	1,760.00
Jackson	...	15	.....	9,800	....	653.3	.....	8.388	.....	822.00
Lewis	...	479	.....	347,842	....	726.2	.....	9.599	.....	33,389.16
Monroe	...	21	.....	15,946	....	759.3	.....	9.395	.....	1,498.05
Pocahontas	...	6	.....	3,900	....	650.0	.....	9.230	.....	360.00
Randolph	...	27	.....	17,780	....	658.5	.....	9.426	.....	1,676.00
Ritchie	...	23	.....	16,400	....	713.0	.....	9.108	.....	1,493.75
Roane	131	41	89,368	30,260	682.2	738.0	9.357	9.161	8362.09	2,772.25
Upshur	...	134	.....	102,965	....	768.4	.....	8.543	.....	8,796.51
Wirt	5	...	3,750	.....	750.00	....	6.779	.....	254.22	.....
Total	153	778	105,096	570,068	686.9	732.7	$ 9.237	$ 9.355	$9707.86	$53,329.27

[1]Home weight. [2]Home price.

TABLE 47— *Number of heifers weighing[1] from 550 to 849 pounds, total weight, average weight, average price[2] per cwt., and total value, by counties and by agency of marketing (cooperative or non-cooperative), 1929*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	...	23	.....	15,320	....	660.8	$	$ 9.003	$	$ 1,379.20
Doddridge	5	...	3,924	.....	784.8	....	7.172	.....	281.42	.....
Greenbrier	14	30	9,952	23,050	710.9	768.3	9.187	9.518	914.33	2,193.88
Harrison	...	27	.....	21,650	....	801.9	.....	10.000	.....	2,165.00
Jackson	...	95	.....	73,410	....	772.7	.....	9.131	.....	6,703.35
Lewis	...	152	.....	117,175	....	770.9	.....	8.753	.....	10,255.93
Monroe	...	14	.....	11,410	....	815.0	.....	8.999	.....	1,026.76
Pocahontas	...	138	.....	96,200	....	697.1	.....	7.474	.....	7,190.00
Randolph	...	12	.....	9,600	....	800.0	.....	11.000	.....	1,056.00
Ritchie	...	50	.....	33,425	....	668.5	.....	9.492	.....	3,172.70
Roane	137	143	88,366	111,100	645.0	776.9	8.146	9.559	7198.41	10,619.63
Upshur	...	123	.....	94,680	....	769.8	.....	8.339	.....	7,895.50
Wirt	10	...	7,436	.....	743.6	....	7.569	.....	562.81	.....
Total	166	807	109,678	607,020	660.7	752.2	$8.167	$ 8.840	$8956.97	$53,657.95

[1]Home weight. [2]Home price.

TABLE 48—*Number of heifers weighing[1] from 850 to 1049 pounds, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1928*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	1	64	937	57,580	937.0	899.7	$ 6.260	$10.107	$ 58.66	$ 5,819.70
Braxton	24	4	20,590	3,670	857.9	917.5	9.889	10.000	2,036.24	367.00
Greenbrier	...	36	.....	34,236	....	951.0	.....	9.673	.....	3,311.53
Jackson	...	26	.....	24,650	....	948.1	.....	9.931	.....	2,448.00
Lewis	...	383	.....	361,897	....	944.9	.....	9.717	.....	35,166.62
Monroe	...	32	.....	30,023	....	938.2	.....	10.229	.....	3,071.20
Pocahontas	...	5	.....	4,500	....	900.0	.....	9.000	.....	405.00
Randolph	...	30	.....	26,850	....	895.0	.....	9.400	.....	2,523.88
Ritchie	...	19	.....	17,788	....	936.2	.....	9.811	.....	1,745.20
Roane	99	81	91,932	78,315	928.6	966.9	10.135	9.444	9,317.13	7,396.18
Upshur	...	100	.....	92,275	....	922.7	.....	7.857	.....	7,249.70
Total	124	780	113,459	731,787	915.0	938.2	$10.058	$ 9.498	$11,412.03	$69,504.01

[1]Home weight. [2]Home price.

TABLE 49—*Number of heifers weighing[1] from 850 to 1049 pounds, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1929*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	1	96	886	91,095	886.0	948.9	$7.230	$ 9.369	$ 64.06	$ 8,534.70
Braxton	..	3	.....	2,915	....	971.7	.....	8.836	.....	257.57
Doddridge	15	....	14,064	.....	937.6	....	7.831	.....	1101.39	.....
Greenbrier	28	47	26,460	43,069	945.0	916.4	9.436	9.651	2496.70	4,156.46
Harrison	..	12	.....	10,900	....	908.3	.....	8.362	.....	911.50
Jackson	..	7	.....	6,655	....	950.7	.....	10.990	.....	731.39
Lewis	..	706	.....	621,667	....	880.5	.....	10.971	.....	68,202.83
Monroe	..	16	.....	14,570	....	910.6	.....	9.079	.....	1,322.87
Pocahontas	2	....	1,820	.....	910.0	....	8.826	.....	160.63	.....
Randolph	..	75	.....	67,300	....	897.3	.....	10.000	.....	6,730.00
Ritchie	..	35	.....	34,461	....	984.6	.....	8.678	.....	2,990.42
Roane	50	144	45,301	134,072	906.0	931.2	8.033	9.244	3639.12	12,393.61
Upshur	..	101	.....	90,875	....	899.8	.....	10.218	.....	9,285.41
Wirt	1	....	865	.....	865.0	....	7.240	.....	62.63	.....
Total	97	2022	89,396	1,117,579	921.6	914.6	$8.417	$10.336	$7524.53	$115,516.76

[1]Home weight. [2]Home price.

TABLE 50—*Number of heifers weighing[1] from 1050 to 1249 pounds, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1928*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	1	4	1069	4,250	1069.0	1063.0	$6.710	$11.590	$ 71.73	$ 492.75
Braxton	1	...	1060	.....	1060.0	.....	8.700	.....	92.22	.....
Greenbrier	..	2	....	2,230	.....	115.0	.....	7.020	.....	156.45
Lewis	..	63	....	69,927	.....	1110.0	.....	8.760	.....	6,125.43
Monroe	..	7	....	7,360	.....	1051.0	.....	10.500	.....	772.80
Randolph	..	3	....	3,600	.....	1200.0	.....	10.250	.....	369.00
Ritchie	..	8	....	9,000	.....	1125.0	.....	7.800	.....	702.00
Roane	2	9	2255	9,450	1127.5	1050.0	8.216	9.947	185.28	940.00
Upshur	..	4	....	4,380	.....	1095.0	.....	10.863	.....	475.80
Wirt	1	...	1100	.....	1100.0	.....	7.670	.....	84.37	.....
Total	5	100	5484	110,197	1098.8	1102.0	$7.907	$ 9.106	$433.60	$10,034.23

[1]Home weight. [2]Home price.

TABLE 51—*Number of heifers weighing[1] from 1050 to 1249 pounds, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1929*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	..	9	.....	9,770	.....	1085.5	$	$10.194	$	$ 996.00
Greenbrier	7	10	7,827	10,850	1118.1	1085.0	10.123	10.576	792.30	1,147.50
Harrison	..	2	.....	2,380	.....	1190.0	.....	10.500	.....	249.90
Jackson	..	30	.....	32,950	.....	1098.3	.....	9.134	.....	3,009.62
Lewis	..	22	.....	24,260	.....	1102.7	.....	11.043	.....	2,679.10
Monroe	..	10	.....	11,300	.....	1130.0	.....	12.280	.....	1,388.00
Randolph	..	3	.....	3,450	.....	1150.0	.....	10.250	.....	353.62
Ritchie	..	1	.....	1,100	.....	1100.0	.....	11.000	.....	121.00
Roane	3	26	3,405	27,400	1135.0	1053.8	7.599	10.782	258.74	2,954.20
Upshur	..	10	.....	10,900	.....	1090.0	.....	11.000	.....	1,199.00
Wirt	1	...	1,079	.....	1079.0	.....	1.110	.....	11.98	.....
Total	11	123	12,311	134,360	1119.2	1092.4	$ 8.635	$10.493	$1063.02	$14,097.94

[1]Home weight. [2]Home price.

TABLE 52—*Number of calves weighing[1] less than 250 pounds, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1928*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	127	8	21,939	1,142	172.7	142.8	$11.712	$13.839	$ 2,569.52	$ 158.04
Braxton	148	38	23,280	6,065	157.3	159.6	10.447	7.264	2,432.09	440.59
Greenbrier	...	42	.....	6,457	....	153.7	.....	5.677	.....	366.54
Harrison	2	37	446	6,151	223.0	166.2	14.294	12.032	63.75	740.12
Jackson	...	17	.....	3,016	....	177.4	.....	11.795	.....	355.73
Lewis	...	1	.....	225	....	225.0	.....	10.000	.....	22.50
Ritchie	...	29	.....	5,031	....	173.5	.....	11.264	.....	566.70
Roane	144	1	26,719	215	185.5	215.0	11.609	11.000	3,101.73	23.65
Upshur	...	13	.....	2,047	....	157.5	.....	11.417	.....	233.70
Wirt	451	...	82,667	.....	183.3	....	13.591	.....	11,235.68	.....
Total	872	186	155,051	30,349	177.8	163.2	$12.514	$ 9.580	$19,402.77	$2907.57

[1]Home weight. [2]Home price.

TABLE 53—*Number of calves weighing[1] less than 250 pounds, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1929*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	154	21	24,478	3,745	158.9	178.3	$11.379	$11.092	$ 2,785.38	$ 415.40
Braxton	58	...	9,475	.....	163.4	....	11.053	.....	1,047.26	.....
Doddridge	2	...	318	.....	159.0	....	10.899	.....	34.66	.....
Greenbrier	11	4	2,615	600	237.7	150.0	9.574	13.333	250.35	80.00
Harrison	...	27	.....	3,732	....	138.2	.....	11.946	.....	445.84
Jackson	...	29	.....	5,301	....	182.8	.....	14.687	.....	778.54
Pocahontas	7	...	1,375	.....	196.4	....	10.217	.....	140.49	.....
Randolph	8	...	1,430	.....	178.8	....	.....	10.643	.....	152.20
Ritchie	...	38	.....	5,900	....	155.3	.....	10.900	.....	643.10
Roane	178	19	30,583	3,675	171.8	193.4	11.816	11.605	3,613.75	426.50
Upshur	...	28	.....	4,313	....	154.0	.....	13.395	.....	577.72
Wirt	366	...	67,617	.....	187.4	....	13.365	.....	9,037.22	.....
Total	766	174	136,461	28,696	175.9	164.9	$12.391	$12.264	$16,909.11	$3519.30

[1]Home weight. [2]Home price.

During 1928 the association price was $2.93 per cwt., but during 1929 only 13 cents per cwt. above the independent dealer price. It should be recalled in this connection that several of the cooperatives made an especial effort to put veal calves on the market at their proper stage of development, while independent dealers as a general rule did not put forth such effort.

Tables 54 and 55 show the average home price of calves weighing in excess of 250 pounds, sold through the cooperatives, compared with that of calves sold to independent dealers during 1928 and 1929, respectively. The average price of the cooperatives was higher in 1928 but lower in 1929 than the independent dealer price, indicating the same tendency as shown in previous tables dealing with mature animals.

4. Cows

Tables 56 and 57 show the average home price of cows sold through the cooperatives compared with that of cows sold to independent dealers during 1928 and 1929, respectively.

In both years the average price paid for cows by independent dealers was considerably above the price received from sales through the cooperatives, the difference being somewhat greater in 1929 than in 1928. It is doubtful, however, if this is a fair comparison because of the difference known to exist in the kind of cows handled by each agency. All of the cows marketed through the associations went to the terminal market, while a percentage (it is not known what percentage) of the cows sold to independent dealers were retained on the farm as milk cows or breeding animals. From this it may be assumed that the cows sold to independent dealers were of better quality than those sent to market by the cooperatives and, therefore, it is to be expected that the price paid by the former would be greater than that received through the latter.

CHANGES IN DEALER, COOPERATIVE, AND TERMINAL MARKET PRICE, 1928 AND 1929

It may be observed from the preceding tables, showing the average prices for steers of the various classes, that there was a considerable decrease in the prices of the steers marketed through the cooperatives in 1929 from the prices received in 1928, while in most weight classes there was a slight increase in the prices paid by independent dealers in 1929 above that paid in 1928.

Table 58 shows the monthly average price of steers on the Pittsburgh market, the average price for the year received by patrons of the cooperative livestock shipping associations, and the average price for the year paid by independent dealers in West Virginia. From this table it may be observed that during the months when the large majority of West Virginia cattle were marketed, August, September, and October, the average prices of steers on the Pittsburgh market

TABLE 54—*Number of calves weighing[1] above 250 pounds, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1928*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	8	3	2,403	1,050	300.4	350.0	$ 7.510	$11.429	$ 180.47	$ 120.00
Braxton	2	2	540	676	270.0	338.0	8.211	7.680	44.34	51.92
Greenbrier	..	3	.....	1,028	....	342.7	.....	9.307	.....	95.68
Jackson	..	1	.....	400	....	400.0	.....	11.875	.....	47.50
Lewis	..	10	.....	4,010	....	401.0	.....	10.000	.....	401.00
Ritchie	..	13	.....	4,760	....	366.2	.....	9.664	.....	460.00
Roane	25	7	7,527	3,000	301.1	428.6	11.302	9.633	850.71	289.00
Upshur	..	48	.....	19,650	....	410.2	.....	8.799	.....	1732.50
Wirt	17	..	4,947	.....	281.0	....	11.632	.....	575.44	.....
Total	52	87	15,417	34,574	296.5	397.4	$10.709	$ 9.249	$1650.96	$3197.60

[1]Home weight. [2]Home price.

TABLE 55—*Number of calves weighing[1] above 250 pounds, total weight, average weight, average price[2] per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1929*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	5	3	1,320	1,200	264.0	400.0	$10.214	$ 7.542	$ 134.83	$ 90.50
Doddridge	2	...	638	.....	319.0	....	6.931	.....	44.22	.....
Greenbrier	..	3	.....	1,200	....	400.0	.....	9.597	.....	115.16
Jackson	..	10	.....	4,015	....	401.5	.....	10.697	.....	429.50
Lewis	..	2	.....	845	....	422.5	.....	6.509	.....	55.00
Monroe	..	1	.....	410	....	410.0	.....	18.293	.....	75.00
Randolph	..	51	.....	20,445	....	400.9	.....	8.579	.....	1754.00
Ritchie	..	21	.....	7,125	....	339.3	.....	11.621	.....	828.00
Roane	23	21	6,883	6,840	299.3	325.7	8.903	11.596	612.78	793.20
Upshur	..	42	.....	16,255	....	387.0	.....	11.692	.....	1900.50
Wirt	24	...	6.719	.....	280.0	....	10.526	.....	707.22	.....
Total	54	154	15,560	58,335	288.1	378.8	$ 9.634	$10.355	$1499.05	$6040.86

[1]Home weight. [2]Home price.

TABLE 56—*Number of cows, all weights*[1] *combined, total weight, average weight, average price*[2] *per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1928*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	4	27	3,901	30,166	975.2	1117.3	$5.392	$9.107	$ 210.34	$ 2,747.08
Braxton	63	28	64,916	28,277	1030.4	1009.9	6.553	7.456	4,254.11	2,108.36
Greenbrier	...	14	.....	13,875	....	991.1	.....	5.630	.....	781.15
Harrison	15	40	13,814	40,000	920.9	1000.0	4.807	6.500	664.04	2,600.00
Jackson	...	7	.....	7,180	....	1025.7	.....	6.992	.....	502.00
Lewis	...	73	.....	75,364	....	1032.4	.....	7.364	.....	5,550.04
Monroe	...	19	.....	19,148	....	1007.8	.....	7.154	.....	1,369.76
Pocahontas	...	4	.....	4,400	....	1100.0	.....	7.500	.....	330.00
Randolph	...	38	.....	40,040	....	1053.7	.....	7.513	.....	3,008.20
Ritchie	...	46	.....	43,889	....	954.1	.....	7.807	.....	3,426.50
Roane	143	8	143,838	8,172	1005.9	1021.5	6.209	8.050	8,930.74	657.84
Upshur	...	20	.....	21,460	....	1073.0	.....	6.943	.....	1,490.00
Wirt	65	...	58,719	.....	903.4	.....	4.669	.....	2,741.79	.....
Total	290	324	285,188	331,971	983.4	1024.6	$5.891	$7.402	$16,801.02	$24,570.93

[1]Home weight. [2]Home price.

TABLE 57—*Number of cows, all weights*[1] *combined, total weight, average weight, average price*[2] *per cwt., and total value, by counties and agency of marketing (cooperative or non-cooperative), 1929*

County	Number of animals		Total weight		Average weight		Average price per cwt.		Total value	
	Coop.	Non-coop.[1]	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.	Coop.	Non-coop.
Barbour	13	23	12,197	24,050	938.2	1045.7	$4.209	$7.576	$ 513.33	$ 1,822.00
Braxton	...	19	.....	18,804	.....	989.7	.....	7.526	.....	1,415.26
Doddridge	13	...	12,076	.....	928.9	.....	5.147	.....	621.53	.....
Greenbrier	9	25	10,169	26,168	1129.9	1047.6	6.702	8.010	681.56	2,096.12
Harrison	...	23	.....	23,065	.....	1002.8	.....	6.102	.....	1,407.37
Jackson	3	12	3,366	12,064	1122.0	1005.3	7.170	6.163	241.34	743.50
Lewis	...	75	.....	76,026	.....	1013.7	.....	8.811	.....	6,698.94
Monroe	...	22	.....	20,587	.....	935.8	.....	7.975	.....	1,641.90
Pocahontas	39	5	42,198	5,500	1082.0	1100.0	5.284	8.000	2,229.93	440.00
Randolph	...	7	.....	7,000	.....	1000.0	.....	8.129	.....	569.00
Ritchie	...	27	.....	24,221	.....	897.1	.....	9.182	.....	1,981.72
Roane	155	35	154,647	36,135	997.7	1032.4	5.640	7.201	8,721.72	2,602.20
Upshur	...	42	.....	31,273	.....	744.6	.....	7.565	.....	2,365.87
Wirt	39	...	38,071	.....	976.2	.....	5.133	.....	1,954.17	.....
Total	271	315	272,724	304,893	1006.4	967.9	$5.487	$7.801	$14,963.58	$23,783.88

[1]Home weight. [2]Home price.

TABLE 58—*Monthly average price per cwt. of steers on the Pittsburgh market,*[1] *average price received by patrons of cooperative shipping associations, and average price paid by dealers in West Virginia, 1928 and 1929*

Month	GOOD STEERS 1100-1300 pounds		GOOD STEERS 950-1100 pounds		MEDIUM STEERS 850 pounds up		COMMON STEERS 850 pounds up	
	1928	1929	1928	1929	1928	1929	1928	1929
January	$13.64	$13.40	$13.38	$13.60	$11.88	$12.55	$ 9.62	$10.65
February	13.61	12.31	13.38	12.44	12.52	11.47	10.55	9.62
March	13.28	13.25	13.16	13.38	12.47	12.38	10.75	10.56
April	13.37	13.68	13.29	13.84	12.76	12.88	11.12	11.12
May	13.55	14.00	13.48	14.25	12.85	13.25	11.40	11.50
June	14.19	14.27	14.19	14.46	13.31	13.50	11.91	11.62
July	14.81	14.79	15.00	14.91	13.69	13.70	11.88	11.48
August	14.97	13.85	15.13	13.87	13.52	12.80	11.30	10.50
September	14.88	13.00	15.00	12.72	13.50	11.97	11.22	10.03
October	13.58	12.50	13.70	12.50	12.70	11.60	10.80	9.85
November	13.28	12.48	13.41	12.54	12.50	11.72	10.66	10.00
December	13.53	12.78	13.65	13.00	12.56	12.06	10.68	10.16
*Association Ave. Price	11.59	9.97	9.80	9.31	9.21	8.35	9.21	8.35
*Dealer Ave. Price	10.92	10.86	10.00	10.29	9.92	9.62	9.92	9.62

*The price given is the average price for steers falling within the weight group indicated.

[1]Data from reports of Livestock, Meats, and Wool Division, Bureau of Agricultural Economics, United States Department of Agriculture.

were considerably lower in 1929 than in 1928. Data in the table show that this difference in prices was better reflected in the cooperative price than in the independent dealers' prices.

Chart 5, constructed from data in Table 58, shows the average monthly price of good steers, weighing 1100 to 1300 pounds, on the Pittsburgh market during 1928 and 1929, and the average home price of steers sold through cooperatives and to independent dealers during those years.

The majority of the cattle were marketed in August and Septem-

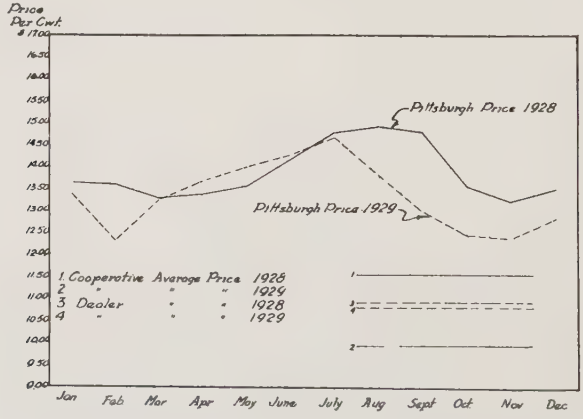


CHART 5—The monthly average price of good steers weighing 1100 to 1300 pounds on the Pittsburgh market, the average home price received by the patrons of the cooperative associations, and the average price paid by dealers for steers of this weight class, 1928 and 1929

ber. The August 1929 terminal market price of steers of this weight was $1.12 per cwt. below the 1928 price. The September 1929 price was $1.88 below the September 1928 price. The October 1929 price was $1.08 below the October 1928 price. For this weight class of steers sold by cooperatives the average price in 1929 was $1.62 below the average price for 1928, while the average price paid by independent dealers in 1929 for this weight of steers was only 6 cents per cwt. below the average price paid in 1928.

Chart 6, constructed from data given in Table 58, shows the changes in the average monthly price of good steers weighing 950 to 1100 pounds on the Pittsburgh market, compared with the changes in the average price for the year received through cooperative sales, and changes in the average price paid by independent dealers.

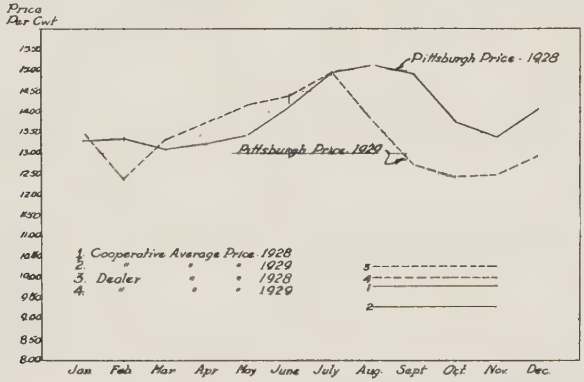

Price Per Cwt.
Pittsburgh Price - 1928
Pittsburgh Price 1929
1. Cooperative Average Price 1928
2. " " " 1929
3. Dealer " " 1928
4. " " " 1929
Jan Feb Mar Apr May June July Aug. Sept Oct Nov Dec.

CHART 6—The monthly average price of good steers weighing 950 to 1100 pounds on the Pittsburgh market, the average home price received by patrons of cooperative associations, and the average price paid by dealers for steers of this weight class, 1928 and 1929

For good steers weighing 950 to 1100 pounds on the Pittsburgh market, the August 1929 average price was $1.26 per cwt. below the August 1928 price; the September 1929 price was $2.28 below the September 1928 price; and the October 1929 price was $1.20 below the 1928 price. The average price for this weight class of steers received from sales through the cooperatives in 1929 was 48 cents lower than in 1928, but for those so'd to dealers the average price was 29 cents per cwt. higher in 1929 than in 1928.

Table 58 shows that for medium steers weighing 850 pounds and up on the Pittsburgh market, the August 1929 price was 72 cents per cwt. below the August 1928 price; the September 1929 price was $2.15 below the September 1928 price; and the October 1929 price was $2 below the October 1928 price.

For common steers weighing 850 pounds and up on the Pittsburgh market, the August 1929 price was 80 cents per cwt. below the August 1928 price; the September 1929 price was $1.19 below the September 1928 price; and the October 1929 price was 95 cents below the October 1928 price.

For steers weighing 550 pounds to 899 pounds the average price received by cooperatives was 86 cents per cwt. lower in 1929 than in 1928, but the average price received for such steers sold to independent buyers was only 31 cents lower in 1929 than in 1928.

These comparisons are sufficient to show that the price of steers which were sold through cooperatives followed the changes in market price more closely than did the price of steers handled by independent dealers. This is offered in proof of an earlier statement (page 11) that the contract system of buying livestock in West Virginia is hazardous to the independent dealer and is considerable of a gamble. This circumstance makes adequate price comparisons over a short period of time difficult. If the market price of livestock is high one year the private dealer is likely to offer a higher contract price for cattle the next year. He contracts cattle for the year ahead on the basis of the present year's market price. Under this system, if cattle prices are rising, the producer receives too little for them, but if the market prices are lower the next year the farmer profits by the contract provided the private dealer is able and willing to carry out his contract. In too many cases he is not able or willing to carry out the provisions of his contract during a falling market and the seller is left to dispose of his cattle as best he can, and often at a lower price than if he had been free to sell earlier in the season.

VII. Summary and Conclusions

The best standard for measuring the efficiency of a private business is the rate of net profit it earns on its capital investment. For the independent dealer in livestock, net profit earned is likewise the best test of his efficiency. The net profit test, however, is not applicable to cooperative shipping associations because they operate as non-profit business enterprises, serving their patrons at actual cost of operation. There is no single standard so adequate for testing the efficiency of a shipping association as is the net profit measure for private business. It is necessary therefore to employ several standards, some of them rather intangible, in testing the efficiency of a cooperative business.

The central purpose of the cooperative associations is to assist the producers in obtaining the greatest possible net return on their livestock enterprises, in so far as marketing affects it. In addition to the individual management of the enterprise, the net return of those patronizing the shipping association is affected by the marketing cost, service, and terminal market price. The net return of those producers who do not patronize the shipping association is affected through its influence on the competing marketing agencies. In measuring the efficiency of a shipping association it is therefore necessary to inquire into costs, services, terminal market prices, and the activities of competitors.

If the marketing service and terminal sales price are equal for both agencies, a cooperative shipping association is more efficient than its competitors if its marketing costs are lower. But a cooperative may operate at a lower cost than its competitors and yet be inefficient if the latter are operating on a high-cost basis. It has not reached its full degree of efficiency until it operates at the minimum cost possible for it to attain under conditions which it cannot further modify. In evaluating the efficiency of such business enterprises it is necessary to analyze their costs and form some judgment of their approach to the possible minimum.

An analysis of the marketing costs of the cooperative livestock shipping associations in West Virginia leads to the conclusion that they are higher than the minimum costs necessary for maximum efficiency and probably higher than those of many competing dealers. The excess of costs above the efficient minimum was due to a combination of small volume of business and poor management while attempting to give adequate marketing service. It appears impossible to apportion the excess in costs to each of these factors.

1. Transportation Costs

Small volume of business was a factor in increasing the transportation costs above the possible minimum. The minimum transportation cost in this state is procured by sending livestock to market by railroad in straight carloads, loaded to the minimum weight fixed by the railroads. In the case of sheep and lambs the minimum rate is procured only by shipment in double-decks. It is possible to load calves with cattle in such a way as to cause no increase in the rate.

This study reveals that most of the cooperative associations transported their cattle at the minimum rate, but that the cost of transporting their sheep, lambs, and calves was considerably in excess of the minimum. A large proportion of the shipments were of mixed carloads, single-decks, and below the minimum weight. One association transported all and another a part of its livestock by truck, thus increasing their costs greatly above the minimum rate by railroads.

There is some evidence to indicate that a part of the excess transportation cost was due to poor management in making up the shipments, but the larger part appears to have been due to small volume coupled with the attempt to make frequent shipments. Of course, the small volume may be attributed to some extent to poor management.

2. Yardage Costs

Since yardage rates were based on the head, neither the number of animals in a car nor the weight of the load had any effect on the total yardage costs, except in the case of the Baltimore market, where

there was a maximum yardage charge per car. This maximum charge is reached by shipping full-loaded cars, and only by a greatly overloaded car may the rate be reduced below the rate on the head basis. Neither management nor volume of business had any appreciable effect on this item of cost.

3. Selling Commission Costs

With the exception of the Pittsburgh market, where a maximum selling charge per car obtained, the selling commission cost was not affected by the number of anima's, weight of load, or kind of shipment. In the case of this market it was not possible to secure the minimum rates except in a straight-shipment, full-loaded car. In many instances mixed shipments increased the selling cost by $3 per car, and truck shipments increased the rate on lambs 150 percent above the minimum on a double-deck carload. For most of the associations that shipped to the Pittsburgh market the selling cost was higher than the minimum cost. This was due to small volume and poor management.

4. Local Car Expense

The items making up the cost which is called local car expense were not uniform for all associations. For the most part local car expense consisted of costs for partitions, bedding, rope, telephone and telegraph charges, etc. In so far as the expense was composed of costs arising from mixed shipments, it a'so was increased because of small volume and poor management. A part of the local car expenses is necessary regardless of the volume of business.

5. Manager's Commission

The manager's commission was paid on the hundredweight basis. This item of cost is not affected by volume except that it might be reduced if there were a sufficient volume to give the manager a satisfactory total return at a lower rate of commission.

6. Insurance Fund

The insurance fund charges were paid on the hundredweight bas'is and hence were not immediately affected by the volume of business. The association expenses and losses are paid out of this fund. Expenses and losses do not increase in direct proportion to the volume of business. Hence an increase in the volume of business would permit either a reduction in this charge or an increase in the amount of patronage dividends.

7. Losses from Death and Injury

Losses from death and injury did not constitute a separate item of cost but were paid out of the insurance fund collections. Anything contributing to such losses therefore prevents a reduction in the insurance fund costs. Data on losses from death and injury were not procured for the West Virginia associations, but a study in the neighboring state of Ohio indicates that such losses are greater in single-decks and mixed shipments. Since a large proportion of the

shipments of the West Virginia cooperatives was in single-deck or mixed shipments, it is probable that the losses were larger than they would have been had there been sufficient volume to permit double-deck, straight shipments.

There is no tangible evidence to show that the marketing costs of the cooperative shipping associations in West Virginia were higher than those of their independent competitors, but the independent dealer operates in such a manner that good management on his part would result in minimum marketing costs. He has control of the livestock which he ships and can call for the delivery of a sufficient number of animals to permit loading in such a way as to result in minimum costs all along the line.

It seems reasonable to conclude that the marketing costs of the shipping associations in West Virginia were greater than they should be for maximum efficiency. The question arises as to the possibility on the part of the associations of lowering these costs. The key to lowering the marketing costs is larger volume and better management.

The ultimate volume for the cooperatives is limited by the comparatively small production in the state, while the potential volume is limited by the activities of the competing independent dealers. It is beyond the province of shipping associations to attempt anything more than minor adjustments in the volume of production. It is, however, clearly within their province to attempt to secure a sufficient share of the production to give them a volume which will permit efficient operation.

MARKETING SERVICE AS A FACTOR IN MEASURING EFFICIENCY

If marketing costs and terminal sales prices are equal for both agencies, the cooperative is more efficient than its competing independent dealers if it renders a more adequate marketing service. But, as in the case of marketing cost, a comparison with the services rendered by competitors is not a sufficient measure of efficiency because the competitors may be giving a low order of service. It therefore becomes necessary to analyze the service given by the cooperative and to form some judgment of its adequacy and economy.

One of the strong arguments favoring the cooperative marketing of livestock is that the producer does not have to put all of his animals on the market at one time. If he has to do this he takes a chance on hitting a temporarily unfavorable market and he also may have to market some animals that are not in condition to bring the best returns. If the cooperative is to render this kind of service it means that it must make shipments at frequent intervals during the marketing season. Some of the cooperatives in West Virginia have given adequate service in this respect; others have not. The asso-

ciation which ships only two or three carloads of livestock during the season can hardly be considered efficient in respect to this kind of service. In attempting to give adequate service many associations have increased their marketing costs.

A common objection to cooperative marketing is that the patron is responsible for the delivery of his animals to the shipping point, while the independent dealer takes possession of them at the farm. This was not a serious objection as long as animals could be driven to the shipping point, since this involved little expense and trouble. But with the extensive construction of hard-surfaced roads, driving animals to the shipping point has become almost impossible. Few farmers own trucks and therefore most are required to hire trucks for hauling their livestock. The independent dealer often has his own truck and can collect the animals directly from the farm. The cooperative associations in West Virginia are deficient in this kind of service. It seems probable that they will have to provide such service if they are to compete successfully with the independent dealer.

The independent dealers are providing a financing service for the producers, a part of which appears to be beyond the province of cooperative associations. This financing service takes two forms: financing the feeding operations, and making loans in the form of advance payments on animals. The first of these is accomplished through the practice of "letting out" livestock for feeding or grazing, in which case the farmer has no capital invested in the animals. It now seems possible for the cooperatives to provide some such financing service as this through the facilities offered by the Federal Farm Board. The independent dealer financing which consists of making loans to small producers appears to have no place in a cooperative shipping association. This is a valuable service in the giving of which the independent dealer appears to hold a superior position.

The cooperative association pays the producer on the basis of the terminal market price. In so far as quality is a factor in the terminal market price it is reflected in the returns to the producer. The independent dealer does not provide such service.

When a producer ships livestock through a cooperative association he is reasonably sure that he will be paid for them. He cannot be so certain of receiving pay from the independent dealer. There are many instances in West Virginia of broken contracts and of payments by check without sufficient funds.

In some respects the marketing services offered by the independent dealers in West Virginia appear to be superior to those offered by the cooperative shipping associations, but in other respects the reverse is true. A larger volume of business would permit the cooperatives to improve their services materially.

THE TERMINAL MARKET SALES PRICE AS A FACTOR IN MEASURING EFFICIENCY

If marketing cost and service are equal for both agencies, the cooperative shipping association is more efficient than its independent dealer competitors, if for the same quality of livestock its terminal market price is consistently higher, or if the cooperative is instrumental in improving the quality of livestock so that it commands a higher price. But again a mere comparison of the terminal market prices is not an adequate test of efficiency, since the competing dealers may be receiving lower terminal market prices than are justified by the quality of the animals sold. In dealing with this measure of efficiency it is necessary to analyze those factors responsible for terminal market price over which the cooperative shipping association has some control, and to form some judgment of its efficiency in dealing with them.

The terminal market sales price depends on three sets of factors: the conditions of supply and demand, the ability of the selling agent, and the quality of the animals. The cooperative shipping association in West Virginia can have little effect on the conditions of supply and demand. The total livestock production of the state comprises a small part of the total sales on the markets where West Virginia livestock is sold. It is, however, sometimes possible upon the advice of well-informed commission merchants to withhold shipments from a glutted market or to rush them into an undersupplied market. West Virginia cooperative shipping associations are hampered in this respect because their shipments are made up of small lots from many farms and it is difficult to make hurried changes in shipping dates. About the best the cooperative can do is to attempt to make regular shipments. The independent dealer is in a better position to take advantage of the fluctuations in the supplies on the market. He has considerable leeway in time in which to take up his livestock and he can ship or hold till a later date as his judgment directs him.

The ability of the commission merchant has some effect on the terminal market price. The manager of the cooperative association is responsible for choosing the commission agent to sell the livestock. Evaluating the ability of the commission merchants on the markets patronized by West Virginia cooperative shipping associations is beyond the scope of this study. Suffice it to say that on the Pittsburgh market the associations sell through a cooperative commission firm, of which they are members. On the other markets the cooperatives sell through the same commission firms that the independent dealers patronize. There are several commission merchants on these markets and any selling advantage which the cooperative might have over an independent dealer would be the result of a wise choice of commission firm to do the selling. Many advantages are claimed for the cooperative commission firm. If there are advantages in

selling through such an agency then the cooperatives are losing those advantages by selling through independent commission dealers.

In so far as the terminal market price is the result of the quality of animals sold, it appears as though the cooperatives in West Virginia have done much toward securing a higher terminal market price for their patrons. The improvement in quality has come about through the efforts of agencies working with the shipping associations, but without the cooperatives' paying for livestock on a quality basis it is doubtful if any great success would have attended the efforts of the other agencies.

The cooperative has an incentive to improve the quality, for with costs as they are the price received by the producer is dependent upon the terminal market price. On the other hand the independent dealer has little incentive to encourage improvement in quality. His profit depends on the difference between his selling price and buying price plus expenses. If his terminal market price is low he cannot pay so much for the livestock as if the terminal price were higher, but this need not affect his profit. In fact purchasing animals on a quality basis is a distinct source of trouble and extra expense to the independent dealer.

The work of the cooperatives in the improvement of the quality of livestock in West Virginia is probably their greatest achievement. Yet the work, just begun, cannot become fully effective until a larger part of the producers patronize those associations which pay according to quality.

THE EFFECT OF COOPERATIVE ASSOCIATIONS ON THE ACTIVITIES OF THEIR COMPETITORS AS A MEASURE OF EFFICIENCY

If a cooperative association is instrumental in raising the plane of competition it may be considered to have elements of efficiency. The effects of a cooperative on the activities of its competitors are most difficult to measure. It may result in decreased margins and improved service on the part of the independent dealers so that producers who sell to them receive just as good or better service and prices as those who patronize the cooperative. If it is shown that the cooperative service is adequate and that their costs are near the minimum, then, if the independent dealers are paying prices equal to or better than the cooperative price, it must be concluded that they are operating on a very narrow margin or perhaps taking losses.

Data presented in the body of this report are not sufficient for a conclusive statement on prices received from the two agencies but they indicate that in 1928 dealers paid about as much as farmers received through the cooperative and in 1929 paid a higher price than the cooperative price.

Many of the dealers are speculators and hence a part of the price paid was speculative. In periods of rising prices there is also more competition between independent dealers. It seems improbable that independent dealers can continue to pay prices higher than the co-

operative price. Many of them lost heavily on their speculative buying of 1929 and some have had to give up their buying operations because of depleted capital.

The mere fact that a farmer can sell through a cooperative association if he chooses gives him an advantage in bargaining and has some weight in forcing the dealer to pay a price equal to the cooperative price. Cooperatives may be quickly organized or revived and in a state that has had experience with them the mere threat of an active association has an influence on the prices paid by the independent dealer. More and more the farmers are getting away from the practice of selling their livestock on contract, and independent dealers are finding it more difficult to buy livestock for less than the cooperative price. The bitter opposition of the independent dealers to the cooperatives is excellent proof that they are feeling the competition.

The cooperative shipping associations in West Virginia can become more effective in raising the plane of competition if they can increase their volume of business and secure better management so that costs may be reduced and service improved.

Bibliography*

Ashby, R. C. livestock truckage rates in illinois, with a comparison of marketing expense by truck and rail. Ill. Agr. Exp. Sta. Bul. 324, 1930.

Burmeister, C. A., Conway, H. M., and Brodell, A. P. economic factors affecting the beef-cattle industry of virginia. U. S. Dept. of Agr. Technical Bul. 237, 1931.

Doty, S. W. cooperative livestock shipping associations. U. S. Dept. of Agr. Farmers' Bul. 718, 1916.

———— marketing livestock in the south. U. S. Dept. of Agr. Farmers' Bul. 809, 1917.

Durand, E. D. cooperative livestock shipping associations in minnesota. Minn. Agr. Exp. Sta. Bul. 156, 1916.

(1) Fitzgerald, D. A. local cooperative livestock marketing associations in iowa since 1920. Iowa Agr. Exp. Sta. Bul. 254, 1928.

(2) Gaumnitz, E. W., and Black, J. D. organization and management of local livestock shipping associations in minnesota. Minn. Agr. Exp. Sta. Bul. 201, 1922.

Hedges, Harold, and Filley, H. C. cooperative marketing of livestock in nebraska. Neb. Agr. Exp. Sta. Bul. 209, 1925.

(3) Henning, G. F. losses in shipping ohio livestock. Ohio Agr. Exp. Sta. Bul. 438, 1929.

———— market movements of livestock in ohio. Ohio Agr. Exp. Sta. Bul. 409, 1927.

*Only citations referred to in text are numbered.

(4) ———— THE TRUCK AND ITS RELATIONSHIP TO LIVESTOCK MARKETING IN OHIO. Ohio Agr. Exp. Sta. Bul. 440, 1929.

(5) HIBBARD, B. H., FOSTER, L. G., and DAVIS, D. G. WISCONSIN LIVESTOCK SHIPPING ASSOCIATIONS. Wis. Agr. Exp. Sta. Bul. 314, 1920.

JESNESS, O. B. COOPERATIVE LIVESTOCK SHIPPING ASSOCIATIONS. Ky. Agr. Ext. Div. Circ. 104, 1921.

JOHNSON, E. C. MARKETING KENTUCKY LIVESTOCK. Ky. Agr. Exp. Sta. Bul. 278, 1927.

———— and PHILLIPS, C. D. QUALITY AS A FACTOR IN THE PRICE OF KENTUCKY LAMBS. Ky. Agr. Exp. Sta. Bul. 302, 1930.

LOOMIS, RALPH. COOPERATIVE LIVESTOCK SHIPPING ASSOCIATIONS IN MISSOURI. Mo. Agr. Exp. Sta. Bul. 199, 1923.

(6) MACKLIN, THEODORE, and SCHAARS, M. A. MARKETING LIVESTOCK COOPERATIVELY. Wis. Agr. Exp. Sta. Bul. 381, 1926.

MILLER, P. L. DIRECT PACKER BUYING IN THE MARKETING OF LIVESTOCK. Jour. Farm Econ. XI, no. 2, April, 1929.

NOURSE, E. G., and HAMMANS, C. W. COOPERATIVE LIVESTOCK SHIPPING IN IOWA IN 1920. Iowa Agr. Exp. Sta. Bul. 200, 1921.

———— and KNAPP, J. G. THE COOPERATIVE MARKETING OF LIVESTOCK. Published by The Brookings Institution, Washington, D. C., 1931.

PLUMB, C. S. MARKETING LIVESTOCK. U. S. Dept. of Agr. Farmers' Bul. 184, 1903.

(7) REID, T. R. COOPERATIVE SHIPPING OF LIVESTOCK. Ark. Agr. Ext. Div. Circ. 102, 1921.

(8) THOMSEN, F. L., and THORNE, G. B. COOPERATIVE MARKETING FOR MISSOURI. Mo. Agr. Exp. Sta. Bul. 253, 1927.

(9) WALLACE, B. A. COOPERATIVE LIVESTOCK MARKETING IN OHIO. Ohio Agr. Exp. Sta. Bul. 375, 1924.

(10) WILEY, JAMES R. MOTOR TRANSPORTATION OF HOGS TO THE INDIANAPOLIS MARKET. Ind. Agr. Exp. Sta. Bul. 337, 1930.

———— DEATH AND CRIPPLE LOSSES IN SHIPPING HOGS TO MARKET. Ind. Agr. Exp. Sta. Bul. 318, 1927.

COOPERATIVE LIVESTOCK SHIPPING ASSOCIATIONS. U. S. Dept. of Agr. Farmers' Bul. 718, 1916.

LIVESTOCK AND WOOL MARKETING. American Cooperation, vol. II, 1927. Published by The American Institute of Cooperation.

(11) MINNESOTA FARM BUSINESS NOTES, no. 95, Oct. 20, 1930.

ORGANIZATION AND MANAGEMENT OF COOPERATIVE LIVESTOCK SHIPPING ASSOCIATIONS. U. S. Dept. of Agr. Farmers' Bul. 1292, 1923.

Bulletin 250 June, 1932

Varietal Experiments with Red Clover and Alfalfa, and Field Tests with Meadow Mixtures

BY R. J. GARBER AND T. E. ODLAND

Plats of the Meadow-Mixtures Experiment Located on the Agronomy Farm in 1923. Canvas Cock Covers Were Used on the Partly-Cured Hay

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

Varietal Experiments with Red Clover and Alfalfa, and Field Tests with Meadow Mixtures

by R. J. GARBER and T. E. ODLAND†

THE TOPOGRAPHY of West Virginia makes large areas of its agricultural land adapted primarily for hay or pasture crops. Unfortunately much of the hay produced is inferior because of choice of variety or because meadows have been allowed to "grow up" in wild grasses and weeds. The choice of kind and variety of crop is only one of several important considerations in connection with the production of hay. Drainage, cultural methods, liming, adequate fertilization, and proper curing are all essential. Such crops as sweet clover and alfalfa, for example, cannot be grown on a highly acid soil. Alfalfa seems to require a more productive soil than does sweet clover. The legumes in general are somewhat more difficult to cure than the grasses.

The purpose of this bulletin is to give the results of field investigations which were begun several years ago by the Agricultural Experiment Station to help the farmer with the proper selection of crops for hay. It will be convenient to discuss the results of the investigations in three sections — (I) Red Clover, (II) Alfalfa,* and (III) Meadow Mixtures.*

I. Red Clover

Unadapted seed has been one of the causes for the reduction in the acreage of red clover in West Virginia during recent years. This fact was illustrated in a striking manner by some experiments carried on by this Station recently.

Each year considerably more red clover is seeded than is produced in the United States; hence it is necessary to import seed from foreign countries. In West Virginia very little red clover seed is produced, although the South Branch Valley and the Eastern Panhandle do produce some seed. The total amount of red clover seed produced locally, however, does not nearly meet the demand in the state; consequently seed must be shipped in from other sources. In view of this situation the question of adaptability of seed becomes highly important. The experiment reported herein was undertaken to determine for West Virginia the relative adaptability of red clover seed from various sources.

---

†Formerly associate agronomist at the West Virginia Agricultural Experiment Station; now agronomist at the Rhode Island Agricultural Experiment Station.

*The authors are indebted to D. R. Dodd, formerly assistant agronomist at the West Virginia Station, for general supervision of the alfalfa and meadow experiments in 1929.

SOURCE OF SEED

Seed from strains of red clover grown in different sections of the United States and in several foreign countries was obtained through the Office of Forage Crops and Diseases, United States Department of Agriculture, from Wisconsin, Idaho, Ohio, Tennessee, Michigan, Oregon, France, England, Chile, Roumania, Hungary, and Italy. The performance of strains from such widely separated sources should give a fairly trustworthy index of differences with reference to adaptability to West Virginia conditions.

METHODS

Each strain of clover was seeded with oats in three 1/80 acre plots systematically distributed. The oats was seeded at the rate of 1 bushel per acre and was cut early for hay. The clover was seeded at the rate of 15 pounds per acre. All clover plots were clipped late in the summer of the year they were established and the clippings were permitted to remain on the ground.

During the second year two crops of hay were obtained. At the time the field weights of the hay were determined, samples were collected and placed in the drying house to ascertain the amount of moisture carried. Later the yields of hay in tons per acre were calculated on the basis of 15 percent moisture and they are so expressed in Table 1.

TABLE 1—*Average percentage of winterkilling and of weeds in hay, and yields in tons per acre of clover strains from various sources grown at Morgantown, West Virginia, in 1926-28*

Source	No. of years in test	Total no. of plots for test	Average winter-killed	Average weeds in hay		Average yield in tons per acre		
				First cutting	Second cutting	First cutting	Second cutting	Total
Column: (1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
			percent	*percent*	*percent*			
Ohio	3	9	12	5	6	1.22	1.16	2.38
Wisconsin	3	9	4	5	7	1.20	1.08	2.28
Michigan (Check)	3	30	9	6	10	1.23	1.00	2.23
Tennessee	3	9	4	4	5	1.06	1.13	2.19
Idaho	3	9	12	6	6	1.16	1.02	2.18
Oregon	3	9	18	12	25	1.03	0.84	1.87
Chile	3	9	46	31	48	0.85	0.37	1.22
France	3	21	41	37	59	0.83	0.39	1.22
Roumania	3	9	18	19	40	0.82	0.38	1.20
Hungary	3	9	21	28	47	0.82	0.36	1.18
England	2	6	32	28	45	0.63	0.43	1.06
Italy	3	9	55	61	79	0.40	0.22	0.62

Notes were taken on the estimated stand in the fall and in the following spring, on the prevalence of anthracnose before each cutting, and on the relative amount of weeds in the hay.

Three similar experiments were carried on at Morgantown during the period from 1926 to 1928, inclusive. In addition, small quantities of Michigan, Italian, French, Oregon, and Roumanian seed in 1926 and of French, Russian, and Tennessee seed in 1927 were sent for trial to about 30 farmers in West Virginia.

RESULTS

In Table 1 are shown the data collected for the clover strain test at Morgantown. Average yields in tons of hay containing 15 percent moisture, average percentage of weeds in the hay, and average percentage of winter killing, together with certain other data, are presented. It will be noted from the second column of the table that all the clover strains, except the one from England, were tested during three years. The total number of plots which were employed is shown in the third column. The strain from Michigan was used as the check, which accounts for the large number of plots of this sort. Three strains of French origin were tested one year and two strains during the other two years, thus accounting for the 21 plots required for the seed from France. The number of plots of each of the other clover strains was as planned: i. e., three plots per year.

A view of the strain test with medium red clover on the Agronomy farm in 1926

The average yields of hay in tons per acre recorded in the last column of Table 1 show the Ohio strain in first, Wisconsin second, Michigan third, Tennessee fourth, Idaho fifth, and Oregon in sixth place. All of the American strains except the one from Oregon produced an average yield of hay for the two cuttings of more than two tons per acre. The Oregon strain gave an average yield more than one-half ton greater than the highest-yielding foreign strain. The seed from Chile, France, Roumania, Hungary, England, and Italy did not give satisfactory results in these tests. The seed from Italy produced exceptionally low yields and proved wholly unadapted to West Virginia conditions.

The average percentages of weeds in the hay are shown in columns 5 and 6. The second cutting of hay showed a somewhat higher percentage of weeds than the first cutting. It will be observed that the average percentages of winter killing recorded in column 4 are

correlated with average percentages of weeds in the hay. The strains of clover from foreign countries suffered more winter injury, and as a consequence the hay contained more weeds than did the hay from domestic strains. Among native strains the one from Oregon showed most winter injury and the hay contained the most weeds.

In addition to the data recorded in Table 1, notes were taken on the prevalence of anthracnose, a disease which frequently causes considerable damage in the southern part of the red-clover belt. All the foreign strains of red clover showed evidence of the disease, particularly after the first cutting. The native strains showed very little anthracnose. This was especially true of the Tennessee seed, which has been bred for resistance to this disease.

The results of the strain test with red clover carried on in cooperation with about 30 farmers in West Virginia were, in general, similar to the results obtained at Morgantown. In the former case no attempt was made, except in a few instances, to obtain careful yield records. However, general observations indicated that the particular foreign strains of red clover included in these tests did not compare at all favorably with the native strains.

II. Alfalfa

The acreage of alfalfa in West Virginia has increased particularly during recent years. However, the ratio of number of acres of alfalfa to number of dairy cows in the state is still much below that in the adjoining states of Virginia, Maryland, Pennsylvania, and Ohio. West Virginia may well increase her alfalfa acreage severalfold.

One of the important problems in connection with growing the crop is to obtain seed of a variety adapted to local conditions. Seed of common alfalfa produced under climatic conditions less rigorous than those of West Virginia is not as likely to be adapted to the state as seed of "common" produced in a cooler climate.

During the late summer of 1924 the West Virginia Station, in cooperation with the Office of Forage Crop Investigations, United States Department of Agriculture, began some varietal experiments to compare strains and varieties of alfalfa and also to compare the same variety from different sources. Most of the seed* for this work was supplied by the U. S. Department of Agriculture.

METHODS

The varietal experiments were carried out on the Agronomy farm near Morgantown. Seedlings were made in rod-row plats twenty feet long and three feet apart. The rate of seeding was twenty pounds per acre. All seed was inoculated. At harvest the end plants of a row were discarded and the balance placed in muslin bags and hung in a drying house. After the green material had been dried to a constant weight (moisture content between 1 and 2 per-

*The seed obtained from the United States Department of Agriculture was supplied through the courtesy of H. L. Westover.

cent) it was weighed and yield determined in terms of tons of dry hay per acre.

Two separate alfalfa varietal experiments were conducted. One was established in August, 1924, and the other in August, 1928. Crops were removed for three years from the former and for two years from the latter. In each year in which the experiments were under way, except in 1930, three cuttings were removed. During 1930, an abnormally dry year, only two cuttings were removed.

The soil on which these field trials were made is Dekalb silt loam of rather low productivity. At the beginning of each experiment two tons of lime per acre were applied and in addition, ten tons of manure and 200 pounds of superphosphate per acre were used as fertilizers. The plats established in 1924 received a top dressing of 200 pounds per acre of superphosphate during the spring of 1927, and the plats established in 1928 received a similar top dressing in the spring of 1930.

RESULTS OF VARIETAL EXPERIMENTS ESTABLISHED IN 1924

In Table 2 the results of the alfalfa varietal experiments are presented. In column 1 the variety names where known are given; otherwise the places of origin of the seed are used for the variety names. The state or country in which the seed was produced is shown in parenthesis. In case of "common" alfalfa the name of the state where the seed was produced is used in the variety name. The United States Department of Agriculture accession number is shown in column 2 for each strain obtained from the Office of Forage Crop Investigations. Columns 3, 4, and 5 show estimated stands, column 6 the number of plats, and columns 7, 8, 9, and 10, the average yields of dry hay per acre obtained during the three years, 1925 to 1927, inclusive. It should be noted that yields are expressed on the basis of dry hay, not air-dry hay. The latter usually contains from 15 to 20 percent moisture. The yields of dry hay are therefore considerably lower than they would be if expressed as air-dry hay.

The varieties Lebeau, from Michigan, and Cossack, from Montana, produced the greatest average yields (2.22 tons) of dry hay per acre for the three-year period, 1925 to 1927, inclusive. The Grimm variety, from Minnesota, gave an average yield only 0.1 of a ton less than the heaviest yielders among those tested. The average yields of Cossack and Baltic, both from South Dakota, also gave average yields in excess of 2 tons per acre. Other varieties which proved satisfactory in this experiment and which are commercially available are, in descending order of their average yields: Canadian Variegated from Ontario, Common from Utah, Common from Nebraska, Grimm from both Montana and South Dakota, and Common from South Dakota. The Common seed from Kansas gave an average yield (1.69 tons per acre) somewhat less than any of the other Common seed mentioned. In fact, one of the most interesting facts brought out by Table 2 is the variation in yields of Common alfalfa

TABLE 2—*Yields and estimated stands of alfalfa varieties and strains grown on the Agronomy farm from 1925 to 1927, inclusive*

Name and place grown	U. S. number	Estimated stand in percent			No. of plats	Yield per acre in tons dry hay			Average yield per acre, tons dry hay
		Spring 1925	Spring 1926	Spring 1927		1925	1926	1927	1925-26-27
Column: (1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*
Lebeau (Michigan)	2347	81	92	88	5	2.05	2.59	2.02	2.22
Cossack (Montana)	.....	96	99	95	2	2.18	2.69	1.78	2.22
Grimm used as check (Minn.)	.....	87	84	82	35	2.03	2.50	1.84	2.12
Cossack (South Dakota)	2352	97	93	89	5	1.98	2.48	1.72	2.06
Baltic (South Dakota)	1830	93	93	82	5	2.06	2.37	1.71	2.05
Sennpalatinsk (So. Dakota)	.....	99	94	82	2	2.01	2.58	1.35	1.98
Canadian Variegated (Ontario)	2237	97	93	87	5	1.97	2.37	1.55	1.96
Utah Common (Utah)	2234	67	78	79	5	1.69	2.30	1.88	1.96
Cossack (Montana)	.....	96	95	82	2	2.19	2.56	1.12	1.96
South Dakota Common (Nebr.)	.....	89	92	92	3	1.78	2.25	1.73	1.92
Grimm (Montana)	.....	94	89	80	5	1.75	2.26	1.69	1.90
Grimm (So. Dakota)	514	91	86	81	5	1.80	2.12	1.70	1.87
Cossack (Montana)	.....	92	95	87	2	2.06	2.41	1.06	1.84
Dakota Common, from South Dakota seedsman	552	68	90	92	5	1.54	2.14	1.80	1.83
Russian (near Ural Mts.)	28037	87	90	65	5	2.01	2.25	1.21	1.82
Siberia (Western Siberia)	32389	75	95	75	1	1.60	2.57	1.23	1.80
Cossack (Nebraska)	.....	95	93	92	3	1.83	2.50	1.05	1.79
Common, Irrigated (Nebr.)	.....	72	88	85	2	1.80	2.22	1.32	1.78
Argentine, from Maryland seedsman	2346	60	84	57	5	1.72	2.23	1.36	1.77
Grimm (Montana)	.....	92	92	82	5	1.55	2.07	1.60	1.74
Provence (France)	54731	50	75	95	1	1.44	2.10	1.59	1.71
Italian, from N. Y. seedsman	2004	38	81	80	5	1.70	2.12	1.26	1.69
Kansas Common, from Kans. seedsman	533	78	75	79	5	1.58	2.02	1.48	1.69
North Dakota (Nebr.)	.....	73	88	90	3	1.53	2.03	1.51	1.69
Russian (Kuban Russia)	38852	85	75	50	1	1.74	2.36	.63	1.58
Turkestan (Nebr.)	.....	92	89	57	3	1.84	2.10	.72	1.55
Grimm (Nebr.)	.....	94	89	85	3	1.50	1.85	1.10	1.48
Caucasus (Russia)	51157	65	90	10	1	1.70	2.30	.41	1.47
Argentine Chubut, from New York seedsman	2333	32	45	38	5	1.54	1.63	.83	1.33
French "Alps Strain" (France)	54729	15	50	35	1	1.13	1.85	1.00	1.33
Chinese (Mongolia)	31687	46	46	11	5	1.67	1.60	.69	1.32
Chilean (Northern Chile)	24210	10	40	55	4	1.20	1.54	1.18	1.31
Smooth Peruvian (Calif.)	2274	3	6	10	5	1.13	1.56	1.00	1.23
Arizona Common (Ariz.)	2273	7	23	31	5	1.03	1.27	1.26	1.19
Spanish, from N. Y. seedsman	2005	12	40	71	5	.97	1.43	.98	1.13
Provence, from Penna. seedsman	34886	82	83	10	2	1.42	1.64	.25	1.10
French (France)	54730	10	10	10	1	.69	1.53	1.06	1.09
Turkestan (Turkestan)	31333	28	25	21	5	1.10	1.47	.58	1.05
Hairy Peruvian (Arizona)	538	2	8	10	5	1.11	1.16	.61	.96
M. sativa gaetula (Algeria)	26590	50	50	30	1	.85	1.47	.51	.94
Indian (India)	31467	10	26	11	5	.84	1.04	.68	.85
Peruvian (California)	33193	10	5	10	1	.57	.86	.59	.67
Chinese (China)	38464	5	3	10	1	.38	.47	.44	.43

obtained from the several sources. Common from Arizona yielded as an average for the three-year period only 1.19 tons of dry hay, whereas Common from Utah gave an average yield of 1.96 tons during the same period. It is obvious that source of seed is a very important consideration, particularly with Common alfalfa. Unless seed has been produced under climatic conditions at least equally as rigorous as those of West Virginia, the strain or variety may prove unadapted.

In columns 3, 4, and 5 of Table 2 is recorded, in percent, the estimated average stand of plants for each variety during each of the three years. Some varieties such as Chinese (U. S. No. 38,464), Peruvian (U. S. No. 33,193), and India (U. S. No. 31,467) proved wholly unadapted; other varieties such as Caucasus (U. S. No. 51,157) and Provence (U. S. No. 34,886) came through the first two winters satisfactorily but were almost completely killed out during the third winter. In a few varieties, notably Spanish (U. S. No. 2005) and Chilean (U. S. No. 24,210), the stand of plants was estimated to have increased during the progress of the experiment. The varieties which gave the greatest average yields of dry hay for the three-year period withstood the West Virginia winters satisfactorily. Little significance can be attached to the absolute values recorded in these columns, since they are estimates. The values, however, indicate general trends with respect to winter hardiness.

RESULTS OF VARIETAL EXPERIMENTS ESTABLISHED IN 1928

In Table 3 the results are shown of the alfalfa varietal experiment established in 1928. The yields of dry hay per acre for the two-year period (column 7) show that Lebeau produced on the average the greatest quantity of dry hay (2.06 tons per acre per year). For the same period, Disco No. 28 ranked second with an average yield of 2.05 tons per acre; Common from Montana and Utah from a Utah seedsman were tied for third place with average yields of 2 tons per acre. The ten next greatest yielders in descending order are: Dakota Common, Utah Common, Kansas Common, Canadian Variegated, another Utah Common, Cossack from Utah, Cossack from Montana, Oklahoma Common, Common produced under irrigation, and Hardigan. The range in average yields of dry hay for this group of ten is from 1.92 tons to 1.86 tons per acre. Perhaps the most noticeable circumstance about Table 3 is the absence of Grimm from the heavier yielding group. The strains of Grimm gave average yields of dry hay per acre for the two-year period as follows: Minnesota strain, 1.58 tons; Utah strain, 1.62 tons; a strain from a South Dakota seedsman, 1.64 tons; Idaho strain, 1.66 tons; Montana strain, 1.66 tons; a second Montana strain, 1.71 tons; a second Utah strain, 1.72 tons; and a third Montana strain, 1.73 tons.

It will be observed that there is much less variation among the average yields of Grimm than among those of Common. Arizona Common from southern California gave an average yield of only 1.24 tons per acre. This again brings out the fact that strains of

TABLE 3—*Yields and estimated stand of alfalfa varieties and strains grown on the Agronomy farm from 1929 to 1930, inclusive*

Name and place grown	U. S. number	Estimated stand in %, spring, 1929*	No. of plats	Yield per acre in tons dry hay		Average yield per acre, tons dry hay 1929-1930
				1929	1930	
Column: (1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
Lebeau (Michigan)	2622	92	5	2.26	1.86	2.06
Disco No. 28, from S. D. seedsman	14210	97	5	2.26	1.85	2.05
Common (Montana)	.....	97	5	2.14	1.86	2.00
Utah, from Utah seedsman	2561	97	5	2.18	1.82	2.00
Dakota Common, from So. Dak. seedsman	14137	98	5	2.03	1.81	1.92
Utah Common, from Utah seedsman	2623	95	5	2.10	1.74	1.92
Kansas Common, from Kansas seedsman	14181	98	5	2.14	1.69	1.91
Canadian Variegated, from New York seedsman	14154	97	5	2.00	1.80	1.90
Utah Common (Utah)	.....	99	5	2.07	1.74	1.90
Cossack (Utah)	.....	98	5	2.09	1.69	1.89
Cossack (Montana)	.....	98	5	2.10	1.68	1.89
Oklahoma Common (Oklahoma)	14475	94	5	2.10	1.64	1.87
Common, Irrigated (Nebr.)	.....	89	5	1.99	1.73	1.86
Hardigan (Michigan)	2621	96	5	2.02	1.70	1.86
Cossack	2671	94	5	1.95	1.71	1.83
Cossack (Montana)	.....	95	5	1.93	1.68	1.80
South Dakota Common (Nebr.)	.....	99	5	1.81	1.74	1.77
Cossack (Idaho)	.....	98	5	1.88	1.61	1.74
Grimm (Montana)	.....	95	5	1.87	1.59	1.73
Grimm (Utah)	.....	98	5	1.79	1.66	1.72
Common (Idaho)	.....	90	5	1.82	1.61	1.71
Grimm (Montana)	.....	96	5	1.72	1.70	1.71
Ladak (So. Dakota)	14135	95	5	1.84	1.57	1.70
New Mexico Common (N. M.)	14470	87	5	1.86	1.52	1.69
Orenburg (Montana)	.....	90	5	1.66	1.69	1.67
Grimm (Montana)	.....	92	5	1.63	1.69	1.66
Grimm (Idaho)	.....	93	5	1.72	1.60	1.66
Grimm, from S. D. seedsman	14196	90	5	1.60	1.68	1.64
Dakota No. 12, from S. D. seedsman	2668	97	5	1.67	1.62	1.64
Grimm (Utah)	.....	95	5	1.61	1.64	1.62
Turkestan (Nebr.)	.....	91	5	1.87	1.33	1.60
Grimm, used as check (Minnesota)	.....	92	70	1.62	1.54	1.58
Cossack (Montana)	.....	93	5	1.65	1.52	1.58
Russian (near Ural Mts.)	28037	97	5	1.75	1.42	1.58
French (France)	66701	88	5	1.74	1.39	1.56
Turkestan, from Nebr. seedsman	2674	91	5	1.76	1.31	1.53
Russia (Kuban Russia)	38852	71	5	1.55	1.50	1.52
Sand Lucerne, from N. Y. seedsman	36089	62	5	1.43	1.33	1.38
Ecuador (Ecuador)	55488	62	5	1.37	1.29	1.33
Argentine, from Arg. seedsman	14160	70	5	1.52	1.14	1.33
Provence (Chile)	62079	68	5	1.41	1.25	1.33
Russia (Turkestan)	31333	55	5	1.35	1.29	1.32
Arizona Common (So. Calif.)	14469	12	5	1.31	1.17	1.24
Provence (Chubut) from Ill. seedsman	14465	51	5	1.38	.96	1.17
Italian, from N. Y. seedsman	2004	62	5	1.14	1.14	1.14
Chilean (Chile)	62077	44	5	1.14	1.03	1.08
New Zealand (New Zealand)	53448	14	5	.90	1.11	1.00
Chilean (North Chile)	24210	25	5	.91	.90	.90
Arizona Common (So. Calif.)	2638	7	5	.88	.90	.89
California Common (Calif.)	17381	12	5	.92	.83	.87
Italian (Italy)	14206	59	5	.70	.80	.75
African (Union So. Africa)	14202	5	5	.52	.82	.67
Smooth Peruvian (Arizona)	2274	5	5	.64	.55	.59
Spanish, from N. Y. seedsman	7101	10	5	.55	.54	.54
Smooth Peruvian (Arizona)	14183	2	5	.29	.25	.27
Ecuador (Ecuador)	55570	2	5	.31	.18	.24
Peruvian (Chile)	62078	1	5	.15	.18	.16

*Estimate not taken in spring, 1930.

Common alfalfa may or may not be well adapted to West Virginia conditions. In general, seed of Common alfalfa which has been produced under climatic conditions where the winters are relatively cold has proved more satisfactory than seed from sections with mild winters.

An estimate of the relative amount of winter injury among the varieties and strains is indicated in column 3 of Table 3. Here again, as in the earlier experiment, some correlation between average yield and percent stand is apparent.

COMPARISON AMONG COMMON, GRIMM, AND COSSACK VARIETIES

It is interesting to compare the performance of the strains of Common alfalfa with those of Cossack and of Grimm. In Table 4 the average yields per year of the three sorts are shown.

TABLE 4—*Average yields of the strains of Common, of Cossack, and of Grimm in the two alfalfa varietal experiments*

Variety	No. of strains	Average yields in tons of dry hay					
		1925	1926	1927	1929	1930	Average
Column: (1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
1st Experiment							
Common*	5	1.68	2.19	1.64	...	...	1.84
Cossack	5	2.05	2.53	1.35	...	...	1.98
Grimm	5	1.73	2.16	1.59	...	...	1.83
2nd Experiment							
Common†	10	...	...	...	2.01	1.71	1.86
Cossack	6	...	...	...	1.93	1.65	1.79
Grimm	8	...	...	...	1.71	1.64	1.67

*Without Arizona Common.
†Without two strains of Common from Arizona and one from California.

In the first experiment the five Cossack strains averaged greater yields in 1925 and in 1926 but averaged distinctly less than the strains of Grimm and of Common in 1927. In the second experiment the strains of Common (with three of the lowest-yielding strains eliminated) produced the greatest average yields, although the average yields of the strains of Cossack were not very much lower. On the other hand the strains of Grimm averaged distinctly less than those of Common. This may have been owing, in part at least, to seasonal influence. It should perhaps be pointed out that the reduction in average yields between 1929 and 1930 (columns 6 and 7) for the strains of Common was 0.3 tons, for those of Cossack 0.28 tons, and for those of Grimm only 0.07 tons. It is possible that if this experiment had been continued for more than two years the average yields for the entire period would have shown less difference between the strains of Common and Grimm.

III. MEADOW MIXTURES

In August 1921 a series of 96 1/40 acre plats was established on the Agronomy farm for the purpose of determining the yields of air-dry hay of several legumes and grasses, both when grown alone and in mixtures. Owing to the prevalence of sorrel (Rumex acetosella) and chickweed (Stellaria media) some of the plats were plowed and reseeded in 1922. During the summer following removal

of the first crop of hay all the plats were plowed and the entire area was cropped to sweet clover. In 1924 the sweet clover was plowed under and on August 15 the plats, with a few minor changes, were re-established. After the hay crops were harvested in 1925 the plats were again plowed and the next two years the entire area was cropped to corn in order to help subdue the weeds. In the late summer of 1928, plats of 1/80 acre each were seeded with practically the same grass and legume mixtures as had been used in previous years. Smaller plats were used so as to make land available for other purposes. Hay crops were removed in 1929 and 1930, and the average yields of air-dry hay determined.

SOIL AND FERTILIZERS

The soil on which the meadow plats were established is a Dekalb silt loam. The soil was of low productivity and acid in reaction. Before the plats were established, lime at the rate of two tons, and 16% superphosphate at the rate of 200 pounds per acre, were applied. In January of 1922 manure at the rate of ten tons per acre was spread over the plats. In August, 1923, before seeding the sweet clover, the entire area was limed again at the rate of two tons per acre, and superphosphate at the rate of 300 pounds per acre was applied. A second application of ten tons of manure per acre was made in January, 1924. No additional applications of manure or lime were made, but superphosphate was used at the rate of 200 pounds per acre per year. The relatively heavy applications of lime and manure early in the experiment were necessary because of the marked acidity and low productivity of the soil. At the time the experiment was discontinued the soil showed a slightly acid reaction (pH 6.85).

OBTAINING YIELDS

In general the meadow plats were cut when the grass or legume had reached the proper stage of development for making good hay. In the case of the mixtures the predominating grass or legume determined the time of cutting.

All yields were calculated on the basis of tons per acre of air-dry hay. When the partly-cured hay on a particular plat was weighed with a small platform scale, a sample of the material was placed in a large muslin bag and weighed on a metric balance. This sample was then hung in a drying room where it was artificially dried. Later it was taken to a well-ventilated shed and allowed to remain there for several weeks before re-weighing to determine the amount of air-dry hay.

RESULTS

The yields per acre of air-dry hay, together with the rates of seeding, are shown in Table 5. The rates of seeding are in some cases somewhat heavier than those commonly used. Relatively heavy rates of seeding were used in this experiment to insure a good stand of plants.

Because of the low productivity of the soil at the beginning of the experiment and the prevalence of weeds on some of the plats, it

TABLE 5—*Summary of yields of air-dry hay obtained from certain legumes and grasses grown alone and in mixtures on the Agronomy farm, 1922-1930*

Name and rate of seeding	Yield of air-dry hay in tons per acre							
	1922	1923	1925	1929	1930	1922-30	1922-29	1922-25
Column: (1)	(2)†	(3)	(4)	(5)†	(6)	(7)	(8)	(9)
Timothy 15 lbs.	2.42²*	1.33	2.72	t 2.95	2.28	2.34	2.35	2.16
Orchard grass 20 lbs.	1.52	0.81	2.11	t 1.34	.75	1.31	1.44	1.48
Red top 10 lbs.	1.12	0.78	1.97	t 2.75	1.29	1.58	1.65	1.29
Tall oat grass 40 lbs.	2.74²	0.84	4.24²	t 3.24²	1.38	2.49	2.76	2.61
Meadow fescue 20 lbs.	t 0.74	0.66	....	....	....	....	....	....
Perennial rye grass 30 lbs.	1.75	....	1.54	....	....	....	....	....
Italian rye grass 30 lbs.	2.13²	....	....	....	....	....	....	....
Alsike clover 8 lbs.	xt 1.18	1.11	....	2.85²	....	....	....	....
White sweet clover 25 lbs.	xo 0.97	0.91	t 3.37	1.51	....	....	1.69	1.75
Yellow sweet clover 25 lbs.	xt 0.84	1.11	t 1.85	1.32	....	....	1.28	1.27
Mammoth red clover 10 lbs.	xo 1.08	0.96	t 0.95	3.64²	....	....	1.66	1.00
Medium red clover 10 lbs.	xo 1.36	0.78	t 0.58	2.96²	....	....	1.42	0.91
Timothy 10 lbs., med. red clover 8 lbs.	xo 1.61	1.51	3.26²	3.91²	3.01	2.66	2.57	2.13
Timothy 10 lbs., mam. red clover 8 lbs.	xo 1.29	1.80	3.60²	4.49²	2.75	2.79	2.79	2.23
Timothy 10 lbs., white sweet clover 10 lbs.	xo 1.20	1.91	3.85²	3.09²	2.17	2.44	2.51	2.32
Timothy 10 lbs., alsike 5 lbs.	t 2.21²	1.41	3.71²	3.59²	2.91	2.77	2.73	2.44
Timothy 10 lbs., alfalfa 10 lbs.	t 1.79²	1.47	3.92²	....	....	....	....	2.39
Timothy 10 lbs., orchard grass 10 lbs.	t 2.34²	0.69	2.25	....	....	....	....	1.76
Timothy 10 lbs., tall oat grass 20 lbs.	t 2.99²	1.00	1.24²	....	....	....	....	2.74
Timothy 10 lbs., tall oat 16 lbs., alsike 5 lbs.	3.28²	1.10	4.47²	3.75²	1.42	2.80	3.15	2.95
Tim. 10 lbs., orch. grass 10 lbs., alsike 5 lbs.	2.71²	0.91	3.71²	3.50²	.94	2.35	2.71	2.44
Tim. 10 lbs., red top 5 lbs., alsike 5 lbs.	2.43²	1.14	3.79²	....	....	....	....	2.45
Tall oat grass 20 lbs., orchard gr. 10 lbs.	2.38²	0.81	3.88²	....	....	....	....	2.36
Tall oat grass 20 lbs., alfalfa 10 lbs.	2.49²	1.09	4.63²	....	....	....	....	2.74
Tall oat gr. 20 lbs., white sw. clov. 10 lbs.	2.83²	0.82	4.41²	....	....	....	....	2.69
Tall oat gr. 20 lbs., med. red clov. 8 lbs.	2.73²	0.96	4.20²	....	....	....	....	2.63
Orchard gr. 15 lbs., med. red clover 8 lbs.	1.57²	0.61	3.03²	....	....	....	....	1.74
Orchard gr. 15 lbs., white sweet clover 10 lbs.	1.22	0.84	2.14	....	....	....	....	1.40
Orchard gr. 15 lbs., alfalfa 10 lbs.	1.47²	0.84	3.24²	....	....	....	....	1.85
Orch. gr. 10 lbs., tall oat 20 lbs., alsike 4 lbs.	2.60²	0.91	3.91²	3.56²	1.40	2.48	2.74	2.47
Orch. gr. 5 lbs., tall oat grass 8 lbs., timothy 5 lbs., alfalfa 5 lbs., alsike 4 lbs.	2.80²	1.24	4.25²	4.03³	2.26²	2.92	3.08	2.76
Alfalfa 15 lbs., alsike 2 lbs., timothy 5 lbs.	....	....	....	4.47³	2.84	....	....	....
Alfalfa (Nebr. Common) 20 lbs.	....	....	3.31²	4.20³	2.69²	....	....	....
Alfalfa (Grimm) 20 lbs.	xo 0.99	0.90	3.59²	4.01³	2.96²	2.49	2.37	1.83

†All yields average of three plots except where noted otherwise; t = two; o = one.

*Small figures indicate number of cuttings per year, i. e. ² = two cuttings per year. In all other cases a single crop removed.

xPlowed and reseeded during late summer of 1922.

was not possible to follow the original plan in all details. The departures are indicated in the table. Total average yields are based on triplicate plats except where otherwise noted. The number of cuttings per year is also shown in the table.

PURE CULTURES

The average yields for 1923 (column 3) are all rather low because only a single cutting was removed. Perhaps the most satisfactory comparison may be made by examining the total average yields for the several periods shown in columns 7, 8, and 9. Among the pure cultures of grasses, tall oat grass produced the greatest total average yield, timothy next, red top third, and orchard grass fourth, except during the 1922-25 period (column 9), when the positions of red top and orchard grass were reversed. Meadow fescue which was grown for two years only did not give a satisfactory yield. Perennial rye grass produced 1.75 tons per acre from a single cutting in 1922 and 1.54 tons in 1925, whereas Italian rye grass yielded 2.13 tons per acre from two cuttings in 1922, the only year it was grown.

The total average yields of the clovers grown alone are rather low because only a single cutting was taken off during any one season except in 1929 (column 5), when two crops were harvested each of alsike, mammoth red, and medium red clovers. During the 1922-29 period (column 8) white sweet clover produced an average yield of 1.69 tons of air-dry hay, mammoth red clover 1.66 tons, medium red 1.42 tons, and yellow sweet clover 1.28 tons per acre. The average yield of alsike is not directly comparable with these averages as it was not grown in 1925. Considering only the average total yields for 1922, 1923, and 1929, the alsike clover produced about the same amount of hay as medium red clover. The total average yields for these three years are as follows: mammoth red 1.89 tons, alsike 1.71 tons, medium red 1.70 tons, white sweet clover 1.13 tons, and yellow sweet clover 1.09 tons per acre.

Two strains of alfalfa were grown in 1925, 1929, and 1930 — the Common from Nebraska and Grimm from Minnesota. In the mixed cultures the Grimm variety was used. The average yields obtained in 1922 and 1923 were not satisfactory and can not be considered as indicative of the yields obtainable. These low yields serve to show that alfalfa can not be grown successfully in very unproductive soil. It will be recalled that these plats were very unproductive at the beginning of the experiment. After organic matter in the form of barnyard manure, and white sweet clover, along with some superphosphate, had been added to the soil, the alfalfa produced a very satisfactory crop.

Although low yields of the Grimm alfalfa were obtained during 1922 and 1923, the total average yield for the entire period 1922-30 (column 7) — 2.49 tons per acre — compares rather favorably with the other total average yields obtained from the pure cultures and

mixtures grown during the same period. The total average yield of Grimm may be compared with that of Common for the years 1925, 1929, and 1930. During this time Grimm produced a yearly average yield of 3.52 tons of air-dry hay per acre, whereas Common produced 3.4 tons per acre.

MIXED CULTURES

In order to facilitate a comparison of the several meadow mixtures, Table 6 has been prepared. The five mixtures containing tall oat grass, but no timothy, yielded on the average 2.58 tons of hay per acre, and the eight mixtures containing timothy, but no tall oat

TABLE 6—*Average yields of air-dry hay of certain grass and legume mixtures grown during 1922, 1923, and 1925 on the Agronomy farm*

Mixture containing	Number of different mixtures	Average yield of dry hay
Tall oat grass but no timothy	5	2.58
Timothy but no tall oat grass	8	2.27
Tall oat grass but no orchard grass	5	2.75
Orchard grass but no tall oat grass	5	1.84
Timothy but no orchard grass	8	2.46
Orchard grass but no timothy	5	1.96
Tall oat grass and timothy but no orchard grass	2	2.84
Tall oat grass and orchard grass but no timothy	2	2.41
Timothy and orchard grass but no tall oat grass	2	2.10
Alfalfa and tall oat grass	1	2.74
Alfalfa and timothy	1	2.39
Alfalfa and orchard grass	1	1.85
Medium red clover and tall oat grass	1	2.63
Medium red clover and timothy	1	2.13
Medium red clover and orchard grass	1	1.74
White sweet clover and tall oat grass	1	2.69
White sweet clover and timothy	1	2.32
White sweet clover and orchard grass	1	1.40
Alsike clover and timothy	1	2.44
Mammoth red clover and timothy	1	2.23

grass, gave an average yield of 2.27 tons per acre, indicating some advantage in favor of tall oat grass. In a similar manner tall oat and orchard grass may be compared. Here the difference is more pronounced in favor of tall oat grass. The difference between the average yields of the five mixtures containing tall oat but no orchard grass, and the five mixtures containing orchard but no tall oat, is 0.91 tons per acre. The eight mixtures containing timothy but no orchard grass produced an average yield of 0.5 tons more than did the five mixtures containing orchard grass but no timothy. The two mixed cultures containing tall oat and timothy but no orchard grass gave, for the three-year period, an average yield of 2.84 tons; the two mixtures containing tall oat and orchard grass but no timothy, 2.41 tons, and the two containing timothy and orchard grass but no tall oat grass, 2.1 tons per acre. Here again is evident the superiority of tall oat over timothy or orchard grass in ability to yield.

In the legume-grass mixtures the highest average yields were obtained when tall oat was one of the components. The average yields in tons per acre of alfalfa with tall oat, with timothy, and with

orchard grass were 2.74, 2.39, and 1.85, respectively. Medium red clover with the same three grass crops and in the order named produced average yields of 2.63, 2.13, and 1.74 tons per acre. White sweet clover with tall oat grass gave an average yield of 2.69 tons of hay per acre, with timothy 2.32 tons, and with orchard grass 1.40 tons. A mixture of alsike clover and timothy produced somewhat more hay in this experiment than did the mixture of mammoth red clover and timothy.

The outstanding fact shown in Table 6 is that tall oat grass possessed marked ability to yield under the conditions of this experiment. Timothy produced greater average yields than did orchard grass both alone and in mixtures. Alfalfa gave somewhat greater yields in combination with each of the three crops — tall oat, timothy, and orchard grass — than did either medium red clover or white sweet clover in combination with each of the same three crops.

TALL OAT GRASS

Inasmuch as tall oat grass is not commonly grown in West Virginia, a brief description of the plant may be desirable. It is a deep-rooted, long-lived perennial with a "bunch" habit of growth. The flowering part of the plant or panicle resembles oats somewhat. It blooms about ten days earlier than medium red clover. This fact makes it less desirable than timothy for mixtures including either clovers or alfalfa under moist conditions. Tall oat grass should be cut promptly when it begins to bloom, for soon afterward the stems become woody and unpalatable. It should not be seeded alone for hay as it is not as palatable as timothy. Tall oat grass is sensitive to shade and does not grow well under this condition. It will perhaps produce more total dry matter on unproductive soil than any other grass although it responds readily to fertilizers and to lime if the soil shows an acid reaction. It will not do well on a wet, poorly-drained soil. In a young orchard tall oat grass may be very useful in building up the supply of organic matter.

Summary

RED CLOVER STRAIN TEST

The experiments reported here indicate very clearly that one of the causes for failure with red clover may be the use of unadapted seed. Foreign-produced seed, if unadapted, is too expensive for any West Virginia farmer, no matter how cheaply it may be bought. It is more economical to purchase native seed known to be adapted even though it may cost twice as much as unadapted seed.

ALFALFA STRAIN TEST

Varietal experiments with alfalfa were established on the Agronomy farm near Morgantown in 1924 and in 1928. In the first experiment, varieties and strains from 43 sources were compared for a period of three years, and in the second experiment, varieties and strains from 57 sources were compared for a period of two years.

The average yearly yields were based on three cuttings except in 1930, when two only cuttings were harvested.

In the first experiment the variety Lebeau was one of the two heaviest yielders and in the second experiment this variety outyielded all others. Other varieties which gave satisfactory yields and which are available commercially are: Disco No. 28, Grimm, Canadian Variegated, Cossack, Hardigan, and certain strains of Common.

If Common alfalfa is used for seed in West Virginia it is important to obtain a strain that is adapted. A wide range of adaptability, and hence of yield, was found among the strains of Common alfalfa.

MEADOW MIXTURE EXPERIMENT

Various grasses and legumes were grown alone and in mixtures on triplicated 1/40 acre plats in 1922, 1923, and 1925, and on triplicated 1/80 acre plats in 1929 and 1930, on the Agronomy farm near Morgantown. Yields of air-dry hay were determined.

Among the pure cultures alfalfa, tall oat grass, and timothy each produced an average annual yield for the five years in excess of two tons per acre. As an average of four years, white sweet clover yielded somewhat more than yellow sweet clover. During the three years 1922, 1923, and 1929 alsike and medium red clover produced about the same average yields, which were somewhat less than the average yield produced by mammoth red clover during the same years. The rye grasses, meadow fescue, and brome grass did not prove very satisfactory in this experiment. As an average of three years, Grimm alfalfa produced slightly more hay than Common alfalfa from Nebraska.

Among the meadow mixtures those containing tall oat grass gave the highest yields. Timothy and alfalfa also proved to be very satisfactory components to increase yields in the several mixtures in which they occurred. In the mixtures tested in this investigation orchard grass proved to be the least desirable component from the standpoint of yield. The meadow mixtures which produced annual average yields in excess of two tons per acre during the years 1922, 1923, and 1925 are: tall oat, timothy, and alsike; tall oat, timothy, orchard grass, alfalfa, and alsike; tall oat and alfalfa; tall oat and timothy; tall oat and white sweet clover; tall oat and medium red clover; tall oat, orchard grass, and alsike; timothy, red top, and alsike; timothy, orchard grass, and alsike; timothy and alsike; timothy and alfalfa; tall oat and orchard grass; timothy and white sweet clover; timothy and mammoth red clover; timothy and medium red clover. These mixtures are listed in the order of their yields. Tall oat, timothy, and alsike, the mixture first in the list, gave an average annual yield during the three years of 2.95 tons per acre, whereas timothy and medium red clover, the last mixture in the list, produced on an average 2.13 tons annually during the same period. The highest producing mixture during the years 1922, 1923, and 1925 yielded on the average approximately 1/3 of a ton more hay than the highest-producing pure culture, tall oat grass.

BULLETIN 251 JUNE 1932

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

Finishing Calves for the Market as Baby-Beeves, Two-Year-Old, and Three-Year-Old Steers

by E. A. LIVESAY

A Typical Lot of Calves Used in the Experiment

THE MAJORITY of finished cattle going on the market from West Virginia are three-year-old grass-fat steers weighing in the neighborhood of 1300 to 1400 pounds. The demand for cattle of this weight and finish has been declining for many years, and the economy of producing heavy grass-finished steers is questionable. An experiment, reported in this publication, was inaugurated with the object in view of determining if baby beef production has a place in the cattle industry of the state and if two-year-old steers cannot be finished for slaughter to a better advantage than three-year-old steers. Calves were purchased and the experimental work was started on the Animal Husbandry farm at Morgantown during the late fall of 1924. The work continued for a period of six years until the fall of 1930.

METHOD OF HANDLING AND FINISHING CALVES

Good, grade, native Hereford steer calves were used with the exception of one lot of baby beeves and one lot of two-year-old steers, both of good, grade, native Aberdeen-Angus steer calves. All the calves were spring calves, being dropped from March 1 to June 1.

In the late fall of 1924, three lots of eight calves each were started on the experiment. The calves of Lot I were fed a heavy grain ration in drylot and marketed as baby beeves when approximately 15 months of age; Lots II and III were wintered in a manner to produce growth the first and second winters and were grazed on a fair bluegrass pasture during the two grazing seasons. After the second grazing season the steers of Lot II were fed a full grain ration in drylot for a short period before marketing. The steers of Lot III, which were marketed as three-year-old grass-fat steers, were wintered the third winter in a manner to maintain approximately their late fall weight. These steers were marketed from grass near the close of the following grazing season.

When lots of baby beeves, two-year-old, or three-year-old steers were marketed, calves were purchased to replace them. Hence during the six years of the experiment six lots of calves were finished and marketed as baby beeves, three lots as two-year-old steers and two lots as three-year-old steers. The rate of turnover and the length of time it is necessary to tie up capital in calves is emphasized by the fact that twice as many calves can be marketed as baby beeves as can be marketed as two-year-old steers, and one-third more can be marketed as two-year-old steers than as three-year-old steers.

FEEDS AND WEIGHTS

The roughages were all home grown and were of good quality. All of the concentrates were purchased, and the prices used for these feeds are average cost prices for the six-year-period. The value of the roughages was based upon the costs of such feeds in this section during the duration of the experiment. In arriving at the value of loose, home-grown hays and straw the necessary expense of baling and placing such feeds upon the market was deducted from the market price of similar grades sold in this locality. In all cases the animals were fed twice daily. Salt and water were kept before all lots during the various feeding periods. The oats and molasses in the baby beef rations (Table 1) were not fed throughout the feeding periods. Oats was fed heavier the first half of the period and was gradually replaced by corn during the last half. A small quantity of molasses was fed during the last six weeks of the feeding period in 1925, 1926, and 1929. The steers were confined to small, concrete paved lots with open sheds during all finishing and winter feeding periods.

The same pasture was used each year for the cattle finished as two-year-olds and three-year-olds, and was a light bluegrass sod of fair quality. The cost of the pasture was based on the actual rental

value and was prorated according to the age of steers and the season of the year each group was grazed. These pasture costs are considered a fair prorata charge for the steers of various ages and Tables 2 and 3 give the daily and total costs per steer.

The winter feeding periods (including the baby beef lots) began around December 12 each year with the exception of the first lots of calves, which were started the latter part of November (1924). The baby beeves were marketed from June 27 to July 27 each year. The calves which were developed into two-year-old (Lots II-A, II-B, and II-C—Table 2) and three-year-old steers (Lots III-A and III-B—Table 3) were turned to grass from April 17 to May 2 each year. The first grazing period for cattle of Lot II and the first and second grazing periods for the cattle of Lot III extended into the second week of December each year. The cattle of Lot II were removed from grass during the second week of September of the second grazing season and were placed in drylot for a short feeding period (see Table 2). The cattle of Lot III were sold from grass during the third grazing season in the second week of September as grass-fat three-year-old steers (see Table 3).

Each individual steer was weighed at the beginning and end of experimental trials and at 28-day intervals during the interim.

All cattle were marketed through the Producers Cooperative Commission Association, Pittsburgh, except Lot I-B (1926) and Lot I-F (1930). The cattle of Lot I-B (1926) were sold to Crawford's Market, Clarksburg, W. Va., and those of Lot I-B (1930) to the Morgantown Packing Company, Morgantown, W. Va.

RESULTS OF THE EXPERIMENT

Feed and pasture costs are so variable in different sections of West Virginia that one hesitates to apply values to feeds or pastures used in experimental work. However, the following averages were used for feeds in all cost data:

Corn (No. 2)	$ 1.85 per 100 lbs.
Oats (No. 2)	1.70 per 100 lbs.
Cottonseed meal (choice)	45.00 per ton
Linseed oilmeal (old process)	50.00 per ton
Molasses	2.50 per 100 lbs.
Alfalfa hay	20.00 per ton
Mixed hay	17.00 per ton
Oat straw	7.00 per ton
Corn silage	6.40 per ton
Chopped green corn	6.40 per ton

The charges for pasture are indicated in Tables 2 and 3. Readers should apply values applicable to their locality in interpreting the results of this experiment.

Baby Beeves

Complete data for the six lots of baby beeves are given in Table 1. These calves were fed a full grain ration each year and remained in drylot until marketed. At the beginning of these trials corn and

TABLE 1—*Calves Marketed as Baby Beeves*

Item	Lot number and year												Average of 6 lots
	Lot I-A 1925		Lot I-B 1926		Lot I-C 1927		Lot I-D 1928		Lot I-E 1929		Lot I-F 1930		
Number of calves	8		8		6		8		8		8		46
Cost per calf	$ 40.32		$ 32.48		$ 40.00		$ 60.00		$ 60.00		$ 60.00		$ 48.80
No. of days	224		243		224		195		210		225		220
Ave. initial wt.†	504		406		466		485		420		458		456.5
Ave. final wt.	981		937		942		955		835		924		929
Ave. gain	477		531		476		470		415		466		472.5
Ave. daily gain	2.13		2.18		2.12		2.41		1.98		2.07		2.15
Ration													
Cracked corn	8.12		7.98		8.58		9.05		8.23		6.73		
Ground oats	4.61		3.47		2.37		3.09		3.08		3.23		
Linseed oilmeal	1.13		.83		1.07		1.14		.88		.88		
Cottonseed meal	.90		.89		.65		1.14		.64		.49		
Molasses	.12		.04		...		...		.10				
Silage	2.60		2.65		2.66		2.98		2.35		2.48		
Alfalfa	4.12		3.18		3.21		...		...				
Mixed hay	...		...		...		2.44		2.67		5.22		
Feed and Costs Per Steer													
Corn	1818 $ 33.63	1940	$ 35.89	1923	$ 35.58	1764	$ 32.63	1729	$ 31.99	1514	$ 28.01		
Oats	1033 17.56	844	14.35	532	9.04	602	10.23	647	11.00	727	12.36		
Linseed oilmeal	254 6.35	201	5.03	241	6.03	222	5.55	183	4.58	197	4.92		
Cottonseed meal	202 4.55	216	4.86	145	3.26	222	5.00	134	3.01	110	2.47		
Molasses	26 .65	10	.25					20	.50				
Silage	580 1.86	644	2.06	598	1.91	582	1.86	492	1.57	557	1.78		
Alfalfa hay	922 9.22	773	7.73	719	7.19		...		...		...		
Mixed hay	...		...		...	476	4.05	560	4.76	1174	9.98		
Total Cost Feed per Steer	$ 73.82		$ 70.17		$ 63.01		$ 59.32		$ 57.41		$ 59.52		$ 63.87
Cost per cwt. Gain	15.48		13.21		13.24		12.62		13.83		12.77		13.52
Total Cost per Steer	114.14		102.65		103.01		119.32		117.41		119.52		112.67
Necessary Selling Price at Home	11.63		10.95		10.93		12.49		14.14		12.93		12.13
Weight on market	960		917		923		936		805		904		907
Shrink (lbs.)	21		20*		19		19		30		20*		22
Percent shrink	2.14		2.26		2.02		1.99		3.59		2.16		2.36
Selling price	$ 14.00		$ 12.00		$ 12.50		16.00		15.83		10.00		13.39
Return per steer (gross)	134.40		112.44		115.37		149.76		127.43		90.40		
Marketing cost	3.51	trucking	3.12		4.05		4.30		3.75		none		
Profit or loss per steer (net)	+16.75		+6.67		+8.31		+26.14		+6.27		—29.12		+5.84
‡Calf return value	57.07		39.15		48.31		86.14		66.27		30.88		54.64
Ave. hot carcass wt., lbs.	601		583		573		572		477		544		558
Ave. dress per cent (hot wt. by market wt.)	62.60		63.57		62.08		61.11		59.25		60.17		
Ave. dress per cent (hot wt. by home wt.)	61.26		62.22		60.83		59.89		57.12		58.87		

*Not weighed, but shrink allowed purchaser.
‡Represents value to the calf producer had the calves been fed and marketed by the producer as they were in this project.
†All weights of calves and of feeds are given in pounds.

oats were fed in equal amounts (pounds). Each 28 days the oats was gradually replaced by corn until very little oats was fed at the close of the trials. Corn silage was fed at the rate of 4 pounds per day from the start of these trials until the first of May each year, and hay was allowed at liberty throughout the periods. Small quantities of molasses were fed near the close of the period in 1925, 1926, and 1929.

Two calves were lost during the 1927 feeding period. These two calves died within a few days of each other; their deaths probably were due to moldy silage, which was not observed until after the calves became ill. As all calves were weighed individually every 28 days, the total amount of feeds fed up to their deaths was reduced according to their percentage weight of the total lot weight.

The average weight of the calves at the start of the trials was 456.5 pounds. They were fed for an average of 220 days, making an average daily gain of 2.15 pounds, or an average total gain of 472.5 pounds. The average final home weight was 929 pounds and the average market weight, 907 pounds. The cost of gains varied from $12.62 to $15.48 per cwt., the average being $13.52. Five of the six lots of calves returned small profits. The 1930 lot returned an average loss per calf of $29.12. However, for the six lots over the six-year period the average net profit per calf was $5.84. The data show that these calves developed and marketed as baby-beeves returned an average potential value of $54.64. These calves would have returned some additional profit had it been possible to let a few hogs follow them. Because of a rather low grain trough and the small size of the feeding quarters it was not feasible to have hogs follow the steers. The results indicate that calves weighing around 450 pounds and handled as they were in this experiment, can be finished in a satisfactory manner for the market in approximately 220 days. The baby beeves marketed in this experiment without exception carried sufficient finish to bring the top of the market at the time of their sale.

A study of the rations reveals that the most rapid and the most economical gains were made in 1928, and this holds true if all the other lots are figured back to approximately the same length of feeding period. The ration for Lot I-D, 1928, based upon the chemical analyses of feeds made by the department of agricultural chemistry, proved to have a nutritive ratio of 1:5.7, the narrowest ratio of any ration. The least rapid gains, but not the most costly, were made by Lot I-E, 1929, and the nutritive ratio of the ration was 1:7.3, the widest nutritive ratio of any ration. This would indicate that the nutritive ratio of rations for finishing baby beeves should be rather narrow.

Two-Year-Old Steers

Table 2 gives the results of developing calves into two-year-old steers for slaughter. These steers were carried through two winters and two grazing periods and then were given a short grain feeding

period in drylot. It was found that these two-year-old steers could not be finished sufficiently for slaughter on grass alone and a short grain feeding period was necessary. During the experiment two steers were lost through accident.* Lot II-A was fed in a manner which produced more gain during the winter feeding periods than

*One steer fell and broke his neck in pasture as a yearling in Lot II-A, and one steer in Lot II-B was struck by a truck while being driven to pasture and was slaughtered.

TABLE 2—*Calves Marketed as Two-Year-Old Steers*

Item	Lot number and year							
	Lot II-A 1925-26		Lot II-B 1927-28		Lot II-C 1929-30		Average 3 lots	
Number of calves	7		7		8		22	
FIRST WINTER FEEDING PERIOD—calves								
No. of days	142		129		120			
Ave. initial wt.†	489		497		453		479	
Ave. final wt.	631		592		530		584	
Ave. gain	142		95		77		105	
Ave. daily gain	1.00		0.74		0.64		0.79	
Ration								
Corn	1.24							
Linseed meal	.23		.97		.96			
Cottonseed meal	1.02		.97		.97			
Corn silage	17.49		10.85		9.60			
Mixed hay	4.92				3.60			
Alfalfa			3.99					
Total Feed and Cost per Steer								
Corn 176	$ 3.26							
Linseed meal 33	.83	125	$ 3.13	116	$ 2.90			
Cottonseed meal 145	3.26	125	2.81	116	2.61			
Corn silage 2484	7.95	1400	4.48	1165	3.73			
Mixed hay 703	5.98	....	...	436	3.71			
Alfalfa	...	515	5.15					
Total cost	$ 21.28		$ 15.57		$ 12.95		$ 16.60	
PASTURE—FIRST SUMMER								
No. of days	224		234		245			
Ave. final wt.	849		810		795			
Ave. gain	218		218		265		234	
Ave. daily gain	0.97		0.93		1.08		0.99	
Cost (5 cents per day)	$ 11.20		$ 11.70		$ 12.25		$ 11.72	
Total Cost for Year	$ 32.48		$ 27.27		$ 25.20		$ 28.32	
Total Gain for Year	360		313		342		338	
Cost per cwt. Gain for Year	$ 9.02		$ 8.71		7.37		$ 8.37	
SECOND WINTER FEEDING PERIOD—yearling steers								
No. of days	133		142		127			
Ave. final wt.	1000		899		877			
Ave. gain	151		89		82		107	
Ave. daily gain	1.14		0.63		0.64		0.80	
Ration								
Cottonseed meal	1.53		1.45		1.50			
Corn silage	28.39		24.14		24.00			
Mixed hay	4.06		4.62		3.00			
Total Feed and Cost per Steer								
Cottonseed meal 203	$ 4.54	206	$ 4.63	190	$ 4.27			
Corn silage 3776	12.08	3428	10.97	3048	9.75			
Mixed hay 540	4.59	656	5.58	381	3.24			
Total cost	$ 21.21		$ 21.18		$ 17.26		$ 19.88	
PASTURE—SECOND SUMMER								
No. of days	147		128		154			
Ave. final wt.	1095		1127		1172			
Ave. gain	95		228		295		206	
Ave. daily gain	.65		1.78		1.92		1.45	
Cost (10 cents per day)	$ 14.70		$ 12.80		$ 15.40		$ 14.30	
Total Cost for Year	$ 35.91		$ 33.98		$ 32.66		$ 34.18	
Total Gain for Winter and Pasture Period	246		317		377		313	
Cost per cwt. Gain	$ 14.60		$ 10.72		$ 8.66		$ 10.92	

TABLE 2—*Calves Marketed as Two-Year-Old Steers—(Concluded)*

Item	Lot number and year							
	Lot II-A 1925-26		Lot II-B 1927-28		Lot II-C 1929-30		Average 3 lots	
Number of calves	7		7		8		22	
FINISHING PERIOD—two-year-old steers—drylot								
No. of days	80		56		56			
Ave. final wt.	1345		1348		1359			
Ave. gain	250		221		187		219	
Ave. daily gain	3.12		3.95		3.34		3.47	
Ration								
Cracked corn	18.23		22.18		24.00			
Cottonseed meal	.85		3.70		1.44			
Chopped green corn	6.06							
Clover hay	7.37							
Mixed hay			6.66		4.52			
Feed and Cost per Steer								
Corn	1458	$ 26.97	1242	$ 22.98	1344	$ 24.86		
Cottonseed meal	68	1.53	185	4.16	181	1.82		
Chopped green corn	485	1.55						
Clover hay	590	5.31						
Mixed hay			373	3.17	253	2.15		
Total cost		$ 35.36		$ 30.31		$ 28.82		$ 31.59
Cost per cwt. gain		14.14		13.71		15.41		14.42
SUMMARY (ENTIRE PERIOD)								
Cost per calf		$ 39.12		$ 40.00		$ 60.00		$ 46.37
No. of days (total)		726		689		702		707
Ave. initial wt.		489		497		453		479
Ave. final wt.		1345		1348		1359		1351
Ave. gain		856		851		906		872
Ave. daily gain		1.18		1.23		1.29		1.23
Cost feed and pasture		$103.75		$ 91.56		$ 86.68		$ 94.00
Cost per cwt. gain		12.12		10.76		9.57		10.77
Total cost per steer		142.87		131.56		146.68		
Necessary selling price at home		10.62		9.76		10.77		10.38
MARKETING DATA								
Wt. on market		1270		1287		1312		1290
Shrink—lbs.		75		61		47		61
Percent Shrink		5.57		4.52		3.46		4.51
Selling price		$ 10.25		$ 15.50		$ 10.50		
Returns per steer		130.18		199.49		137.76		
Marketing cost		5.19		5.15		5.77		
Total costs		148.06		136.71		152.45		
Profit or loss per steer		—17.88		+62.78		—14.69		
Calf return value		21.24		102.78		45.31		56.44
SLAUGHTER DATA								
Ave. hot carcass wt.		779		777		790		783
Ave. dressing per cent (hot and market wt.)		61.34		60.37		60.21		
Ave. dressing per cent (hot and home wt.)		57.92		57.64		58.13		

†All weights of calves and of feeds are given in pounds.

did Lots II-B and II-C. However, the differences in winter gains were overtaken during the two grazing periods by the cattle of Lots II-B and II-C. This would indicate that calves which are to be carried on pasture for two seasons should be wintered rather economically both as calves and as yearlings.

Rations which will produce from 75 to 100 pounds of winter gains are satisfactory. A ration of approximately 10 pounds of corn silage, 4 pounds of either a good mixed hay or alfalfa hay, 1 pound of cottonseed meal, and 1 pound of linseed meal proved to be a very satisfactory ration for calves weighing between 450 and 500 pounds at the beginning of the winter feeding period. A ration of approx-

imately 24 pounds of corn silage, 4 pounds of mixed hay (clover and timothy), and 1.5 pounds of cottonseed meal proved a satisfactory ration for yearlings weighing around 800 pounds at the start of the winter feeding period.

The steers in these lots were removed from grass during the second grazing season the second week of September, placed in dry-lot, and fed a full grain ration for a short feeding period (56 to 80 days). In these trials it was shown that a short feeding period on a full grain ration will produce more than 200 pounds gain and give a finished product superior to three-year-old steers marketed from grass. The average final weight of these steers was approximately 45 pounds less than the three-year-old steers (Table 3) marketed from grass; besides, they were marketed at an average of 10 months' younger age. The cost of the short grain feeding period was less than the cost of carrying two-year-old cattle another year and marketing from grass. The average cost of the three short grain feeding periods was $31.49 and the average cost of wintering and grazing for another year was $35.16. The hot dressing percentage (based on market weight) ranged from 60.21 to 61.34, which indicates sufficient finish for any retail trade.

The cost of producing 100 pounds gain on calves marketed as two-year-old steers varied from $9.57 to $12.12, or an average for the three lots of $10.77. These three lots returned an average profit of $10.07 per steer, but the steers marketed in the fall of 1926 and 1930 lost money. The steers marketed in the fall of 1928 returned an average profit of $62.78 per steer. Had the calf producer handled these calves as they were handled in this experiment they would have returned him an average potential value of $56.44.

Three-Year-Old Steers

Table 3 gives the data on calves developed and marketed as three-year-old grass-fat steers. These steers were carried through three winter feeding periods and three grazing periods and sold from grass as grass-fat steers towards the end of the third grazing season. As calves these steers were wintered to produce in the neighborhood of 100 pounds of gain. As yearlings and two-year-olds they were wintered in a manner to produce only slight gains. On the basis of the price paid for the calves and the cost of feeds and pasture the first lot showed a profit of $32.02 per steer, while the second lot showed a loss of $35.52 per steer. The average loss for the two lots was $1.75 per steer. Calves handled in this manner returned an average potential value of $47.65. The cost of gains gradually increased each year. The first year (winter feeding period and grazing period) the cost of 100 pounds gain was $7.85; the second year $11.71, and the third year $12.17. The average cost of 100 pounds gain was $10.38 or slightly less than the average cost of 100 pounds of gain in the case of calves fed and marketed as two-year-old steers. The average cost of 100 pounds of gain in the latter case (Table 2) was $10.77.

TABLE 3—*Calves Marketed as Three-Year-Old Steers*

Item	Lot number and year				
	Lot III-A 1925-27		Lot III-B 1928-30		Average
Number of calves	8		8		16
FIRST WINTER FEEDING PERIOD—calves					
No. of days	142		142		
Ave. initial wt.†	485		466		476
Ave. final wt.	576		584		580
Ave. gain	91		118		104
Ave. daily gain	.64		.84		.74
Ration					
Corn silage	16.48		10.37		
Mixed hay	4.06		4.02		
Linseed meal	.23				
Cotton seed meal	1.02		2.02		
Feed and Cost					
Linseed meal	33	$ .82			
Cotton seed meal	145	3.26	287	$ 6.46	
Corn silage	2340	7.49	1472	4.71	
Mixed hay	577	4.90	571	4.85	
Total cost		$ 16.47		$ 16.02	$ 16.25
PASTURE—FIRST SUMMER					
No. of days	224		223		
Ave. final wt.	821		829		
Ave. gain	245		245		245
Ave. daily gain	1.09		1.10		1.09
Cost (5 cents per day)	$ 11.20		$ 11.15		$ 11.17
Total Cost for Year	$ 27.67		$ 27.17		$ 27.42
Total Gain for Year	336		363		349
Cost per cwt. Gain for Year	$ 8.23		$ 7.48		$ 7.85
SECOND WINTER FEEDING PERIOD—yearlings					
No. of days	133		120		
Ave. final wt.	863		836		
Ave. gain	42		7		24.50
Ave. daily gain	.32		.06		.19
Ration					
Corn silage	24.38		24.07		
Mixed hay	2.00		2.05		
Cotton seed meal	1.00		1.02		
Feed and Cost					
Corn silage	3243	$ 10.38	2888	$ 9.24	
Mixed hay	266	2.26	246	2.09	
Cotton seed meal	133	2.99	122	2.74	
Total winter cost		15.63		14.07	$ 14.85
PASTURE—SECOND SUMMER					
No. of days	234		245		
Ave. final wt.	1115		1096		
Ave. gain	252		260		256
Ave. daily gain	1.08		1.06		1.07
Cost (7.5 cents per day)	$ 17.55		$ 18.37		$ 17.96
Total Cost for Year	$ 33.18		$ 32.44		$ 32.81
Total Gain for Year	294		267		280
Cost per cwt. Gain for Year	$ 11.28		$ 12.14		$ 11.71
THIRD WINTER FEEDING PERIOD—two-year-old steers					
No. of days	129		127		
Ave. final wt.	1157		1119		
Ave. gain	42		23		32.5
Ave. daily gain	.33		.18		.25
Ration					
Corn silage	25.00		25.00		
Oat straw	3.53		4.00		
Alfalfa hay	1.47				
Mixed hay			2.00		
Cotton seed meal	1.00		1.00		
Feeds and Cost					
Corn silage	3225	$ 10.32	3175	$ 10.12	
Oat straw	455	1.59	508	1.78	
Alfalfa hay	190	1.90			
Mixed hay			254	2.16	
Cotton seed meal	129	2.90	127	2.86	
Total cost		$ 16.90		$ 16.92	$ 16.91

TABLE 3—*Calves Marketed as Three-Year-Old Steers—(Concluded)*

Item	Lot number and year		
	Lot III-A 1925-27	Lot III-B 1928-30	Average
Number of calves	8	8	16
PASTURE—THIRD SUMMER			
No. of days	138	154	
Ave. final wt.	1389	1400	
Ave. gain	232	281	256
Ave. daily gain	1.68	1.97	1.82
Cost (12.5 cents daily)	$ 17.25	$ 19.25	$ 18.25
Total Cost for Year	$ 34.15	$ 36.17	$ 35.16
Total Gain for Winter and Pasture Period	274	304	289
Cost per cwt. Gain for Year	$ 12.46	$ 11.89	$ 12.17
SUMMARY (ENTIRE PERIOD)			
Cost per calf	$ 38.80	$ 60.00	$ 49.40
No. of days	1000	1010	
Ave. initial wt.	485	466	476
Ave. final wt.	1389	1400	1395
Ave. gain	904	934	919
Ave. daily gain	.90	.92	.91
Cost of feeds and pasture	$ 95.00	$ 95.78	$ 95.39
Ave. cost per cwt. gain	$ 10.51	$ 10.25	$ 10.38
Total cost per steer	$138.80	$155.78	
Necessary selling price on farm	9.63	11.12	
MARKETING DATA			
Weight on market	1314	1380	1347
Shrinks lbs.	75	20	48
Percent shrink	5.39	1.43	3.41
Selling price	$ 13.00	$ 9.10	
Returns per steer	170.82	125.58	
Marketing cost	5.00	5.32	
Total cost	138.80	161.10	
Profit or loss per steer	+32.02	—35.52	—1.75
Calf return value	70.82	24.48	47.65
SLAUGHTER DATA			
Ave. hot carcass wt.	796	Not obtained	
Ave. dress % (hot wt. by market wt.)	60.57		
Ave. dress % (hot wt. by home wt.)	57.31		

†All weights of calves and of feeds are given in pounds.

SUMMARY AND DISCUSSION OF RESULTS

Table 4 gives the summarized data of the entire experiment. Readers should keep in mind that items under Lot I represent the results of finishing six lots of calves as baby beeves; items under Lot II represent the results of finishing three lots of calves as two-year-old steers; and items under Lot III represent the results of finishing two lots of calves as three-year-old steers.

Under the three systems of finishing calves for the market the time factor is important. It required an average of 220 days to finish calves as baby beeves; 707 days to finish calves as two-year-old steers; and 1005 days to finish calves as three-year-old steers. The cost of gains was greater in the case of baby beeves, but because of a higher sale value these calves returned a profit in five out of six years, giving an average annual profit of $5.84 and an average potential value of $54.64 for the calves. The average cost was prac-

tically the same for producing 100 pounds of gain on two-year-old and three-year-old steers, but the average profit on the three lots of calves finished as two-year-old steers was $10.07 against an average loss of $1.75 on the two lots of calves finished as three-year-old steers. The average potential calf value was $56.44 in the case of calves finished as two-year-old steers, and $47.65 for calves finished as three-year-old steers.

The above calculations do not take into consideration such items as labor, taxes, and interest charges. The labor charges were estimated to be 2½ times as great for the two-year-old steers as for the baby beeves and three times as great for the three-year-old steers as for the baby beeves. Taxes were estimated to be more than twice as great for the two-year-old steers as for the baby beeves and more than three times as great for the three-year-old steers as for the baby beeves. Interest charges will run in about the same proportion in favor of the baby beeves as the taxes.

The average initial weight of the calves developed into baby beeves was lighter by 20 pounds than the weight of those developed into two and three-year-old steers. This difference in weight was unfavorable to the potential value shown for the baby beeves. Taking these factors into consideration the calves developed and marketed as baby beeves had a greater potential value than calves developed and marketed as two-year-old or three-year-old steers.

The dressing percentages of the two-year-old and three-year-old groups show that two-year-old steers can be given a full grain ration for a short period (56 to 80 days) following the grazing season and can be marketed with just as much finish as similar steers retained for another year and marketed from grass. Two-year-old cattle finished in this manner were slightly lighter (approximately 50 pounds) in weight, and possessed a smoother and more desirable appearance than the steers carried for another year and marketed from grass as three-year-old grass-fat steers.

TABLE 4—*Summary of Tables 1, 2, and 3*

	Lot I	Lot II	Lot III
Ave. no. of days	220	707	1005
Total no. of calves	46	22	16
Ave. initial cost	$ 48.80	$ 46.37	$ 49.40
Ave. initial wt.	456	479	476
Ave. final wt. (home)	929	1351	1395
Ave. gain	472	872	919
Ave. daily gain	2.15	1.23	.91
Ave. market wt.	907	1290	1347
Ave. shrink	22	61	48
Ave. hot carcass wt.	558	783	† 796
Ave. dress % (hot and home)	60.06	57.95	† 57.31
Ave. cost of feed (including pasture)	$ 63.87	$ 94.00	$ 95.39
Ave. cost per 100 lbs. gain	13.52	10.77	10.38
Ave. total cost	112.67	140.09	144.79
Ave. net sale value	118.51	151.16	143.04
Ave. profit or loss	+5.84	+10.07	—1.75
Ave. return value of calf	54.64	56.44	47.65

†For only one group.

The results also emphasize the fact that a short grain feeding period for two-year-old steers is less expensive than the practice of wintering and grazing these cattle for another season. The total cost of feed (pasture included) was actually $1.39 less and the net return per steer $8.12 greater for the calves marketed as two-year-old steers than for those marketed as three-year-old steers.

The calves used in this experiment returned more net profit to the producer than either to the feeder or to the West Virginia Agricultural Experiment Station. During the duration of this experiment, under West Virginia conditions, cows and calves could have been maintained at an average annual cost of approximately $35.00. These calves were bought at an average price approaching $50.00, which represents a good profit to the producer. Heifer calves can readily be sold as feeders and for baby-beef production they are almost as valuable as steer calves.

In summing up the results of this experiment it would seem that there is a place in West Virginia for the production of more good beef calves. Adjoining states offer a good market for our surplus feeder calves and it is not as speculative a phase of beef production as the finishing of heavy steers. In developing a cow herd for the production of such calves care should be taken that all animals of breeding age are kept free from such diseases as infectious abortion and tuberculosis.

CONCLUSIONS

Calves fed and marketed as baby beeves proved to have a greater potential value than calves fed and marketed either as two-year-old or three-year-old steers.

Calves fed and marketed as two-year-old steers had a greater potential value than calves fed and marketed as three-year-old steers.

Grass alone will not produce sufficient finish on two-year-old steers for slaughter.

A full grain ration in drylot for a short period (56 to 80 days) will produce enough finish to make two-year-old grass steers desirable for slaughter and actually more desirable for the market than three-year-old grass-fat steers.

A short grain feeding period for two-year-old steers is less expensive and produces a more valuable slaughter animal than carrying them another year and marketing them as grass-fat three-year-old steers.

These trials indicate that West Virginia should produce more good beef calves and market them at a relatively young age.

Good beef calves produced in West Virginia should be marketed as feeder calves or finished and marketed for slaughter at a young age.

Bulletin 252 June, 1932

The Fertilization of Apple Orchards. III: A Comparison of Nitrate of Soda and Sulphate of Ammonia

BY H. E. KNOWLTON AND M. B. HOFFMAN

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

*The Fertilization of Apple Orchards. III: A Comparison of Nitrate of Soda and Sulphate of Ammonia**

by H. E. KNOWLTON and M. B. HOFFMAN†

WITH the widely prevalent practice of applying quickly available nitrogenous fertilizers to apple trees have come questions as to the comparative value of the several forms on the market. In making a choice several factors must be considered besides that of actual effects on growth and yield of fruit. Among the most important are comparative costs per unit of nitrogen, mechanical conditions as affecting ease of application, and effects upon the soil reaction.

A number of rather quickly available nitrogenous fertilizers are now on the market. Some are being widely used. Others have not been on sale long enough to demonstrate their value and consequently have not come into general use.

At the time the experiments reported herein were started, only two quickly available nitrogen fertilizers, nitrate of soda and sulphate of ammonia, had attained sufficient importance to warrant testing their comparative value. Nitrate of soda, the older commercial form of nitrogen, contains 15.6% nitrogen, and is probably the most widely used of nitrogen fertilizers in the orchard. It is an imported product, being mined in Chile as guano, purified, and sold to the trade as Chilean nitrate of soda. Most of the nitrate of soda on the market comes from this source, although some is now being produced synthetically. Sulphate of ammonia contains from 20.5 to 20.8% nitrogen and comes from two sources: (1) a by-product obtained from the coking of coal and the production of gas, and (2) a synthetic product involving the fixation of atmospheric nitrogen. Production by the latter method is increasing rapidly and almost equals in tonnage that from by-product sources.

Both forms of nitrogen have good mechanical properties — at least in comparison with other less widely-known products such as cyanamid and calcium nitrate. Both nitrate and sulphate tend to take up moisture when exposed to the atmosphere and as a result form hard lumps. Nitrate of soda is worse in this respect, although in the last year or two changes have been made in the product tending to obviate this defect.

A comparison of the relative costs of these fertilizers is of interest from the practical standpoint. In 1931 for the first time sulphate of ammonia cost less per ton than nitrate of soda, although the former contains one-third more nitrogen. In 1932 cost differences are still more striking, as seen in Table 1.

*This is the third in a series of bulletins issued by this Station on fertilization of apple orchards. Those previously published are W. Va. Agr. Exp. Sta. Bulletins 174 and 203.

†Mr. Hoffman resigned September, 1931.

TABLE 1—*Comparative wholesale* prices of several nitrogenous fertilizers per ton and per unit (20 pounds) of nitrogen. February, 1932*

Nitrogen carrier	Wholesale price per ton	Percent nitrogen content	Price per unit of nitrogen
Nitrate of soda	$40.00	15.6	2.56
Sulphate of ammonia	30.00	20.6	1.45
Cyanamid	32.00	22.0	1.45

*Prices obtained from Baugh and Sons, Baltimore, Md.

THE WEST VIRGINIA EXPERIMENTS

Four experiments are reported in this bulletin. Two are located in the orchard of Mr. L. E. Reynolds near St. Marys, Pleasants County, on the hills above the Ohio River Valley. These will be designated as Experiments I and II. A third experiment (Experiment III) is located in the orchards of Mr. E. F. McDonald near Darkesville, Berkeley County, in the Eastern Panhandle. A fourth experiment (Experiment IV) is in an orchard on a farm known as the Burns place, owned by Frank B. Robinson, near Charles Town, Jefferson County, also in the Eastern Panhandle. Two markedly different soil types are represented, one belonging to the Dekalb and the other to the Hagerstown series.

The St. Marys Experiment

Experiment I was begun in the spring of 1922 on 32-year-old Rome trees. While each tree had received 5 pounds of nitrate of soda in 1921, average terminal growth was only 2 to 3 inches that year. Fertilization in previous years had been inadequate and intermittent. The experiment included four rows or plots of 10 to 12 trees each, located adjacent to the St. Marys fertilizer experiment reported in Bulletins 174 and 203 of this Station. Kinds of fertilizer, time of application, and amounts used per tree were as follows:

Plot 11, 5.2 pounds of nitrate of soda 10 to 15 days before bloom
Plot 12, 5.2 pounds of nitrate of soda at bloom
Plot 13, 3.9 pounds of sulphate of ammonia 10 to 15 days before bloom
Plot 14, 3.9 pounds of sulphate of ammonia at bloom

The report on this experiment covers the period from 1922 to 1927, inclusive.

Experiment II was begun in the same orchard in the spring of 1926. Twenty-four trees were carefully selected according to size and paired to facilitate treatment of data by Student's method. Twelve trees received 5.2 pounds of Chilean nitrate of soda and twelve trees, 3.9 pounds of Arcadian sulphate of ammonia 10 to 15 days before bloom. Only three years' data (1926-1828) were taken, as the experiment had to be discontinued because of changes in the management of the orchard.

Soil in the above-described experiments is a Dekalb silt loam, low in fertility, with a lime requirement of 2 to 3 tons per acre. The sod mulch system of soil management has been used but the soil is

so poor that only a sparse growth of grass and weeds could be supported.

Eastern Panhandle Experiments

Experiment III* was begun in the spring of 1925 on nine-year-old Jonathan trees in the McDonald orchard at Darkesville, Berkeley County. Thirty trees were carefully selected to facilitate pairing by Student's method. Ten trees received 5 pounds of Chilean nitrate of soda, ten trees 3.8 pounds of Arcadian sulphate of ammonia, and ten trees were left unfertilized. Fertilizer applications were made at bloom time instead of 2 to 3 weeks before, as is the common practice. The trees stood in a rather heavy sod, in poor vigor, and were small for their age at the time the studies were begun.

The soil is a Hagerstown clay loam, with occasional lime outcrops, and of average fertility. Lime requirement varies from zero to about a ton per acre.

Experiment IV was started in the spring of 1926 on 25-year-old Arkansas (Black Twig) apple trees in the Robinson (Burns place) orchard in Jefferson County. The Black Twig trees are set 35 x 40 feet with Grimes interplanted one way, making the planting distance 20 x 35 feet. Twenty-four pairs of trees selected for uniformity in size are included in the experiment. One half of the trees have received 4 pounds of Chilean nitrate of soda and the other half, 3 pounds of Arcadian sulphate of ammonia 2 to 3 weeks before bloom. Most of the interplanted Grimes were alive at the beginning of the studies, but they have rapidly been dying with collar blight in the subsequent five years. Because of this, certain pairs adjacent to dead Grimes trees have been discarded during the course of the work.

The soil is a Hagerstown clay loam of good fertility with outcrops of limestone scattered here and there through the orchard. At the beginning of the studies the orchard was in alfalfa. Since then the alfalfa has gradually been choked out by grass and weeds with the result that in 1931 the owner had to break up the sod and reseed it to alfalfa. Lime requirement averaged about a ton per acre at the beginning of the experiment.

COMPARATIVE EFFECTS OF NITRATE OF SODA AND SULPHATE OF AMMONIA ON GROWTH

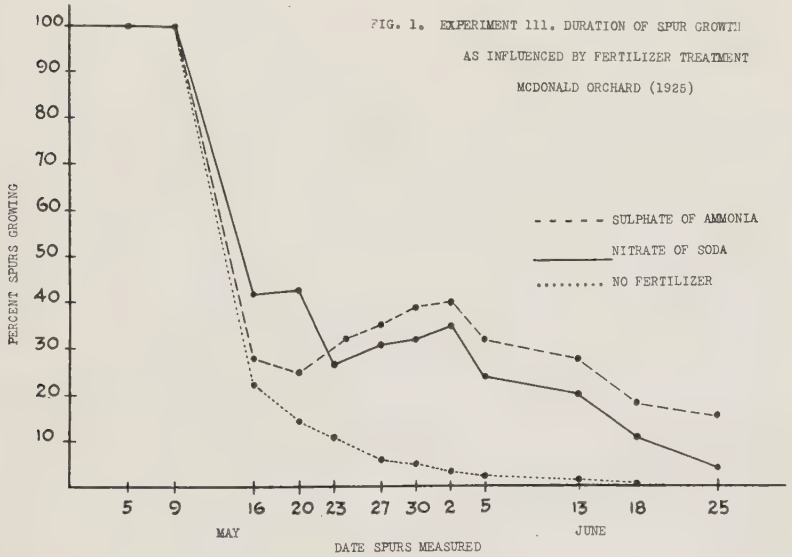
The growth response in these experiments was determined each season by measuring terminal elongation on each tree. While increase in trunk circumference is generally a reliable index of growth, it was believed that in these studies it would be less dependable than terminal growth, for in many of the pairs selected, bearing surfaces were approximately the same on trees with unequal trunk circumferences. In such pairs variation in height of head may have been responsible for the differences.

*Mr. R. C. McDonald collected most of the data on this experiment while a graduate student in West Virginia University.

In taking the terminal twig measurements. twenty shoots were selected at random from the limbs around the sides of the tree, and the total length was taken. It was realized that this figure did not give an index of the actual amount of terminal growth being made by a tree, since growth in the tops is usually greater than around the sides, but it did offer a reliable basis for comparing the effects of the several treatments.

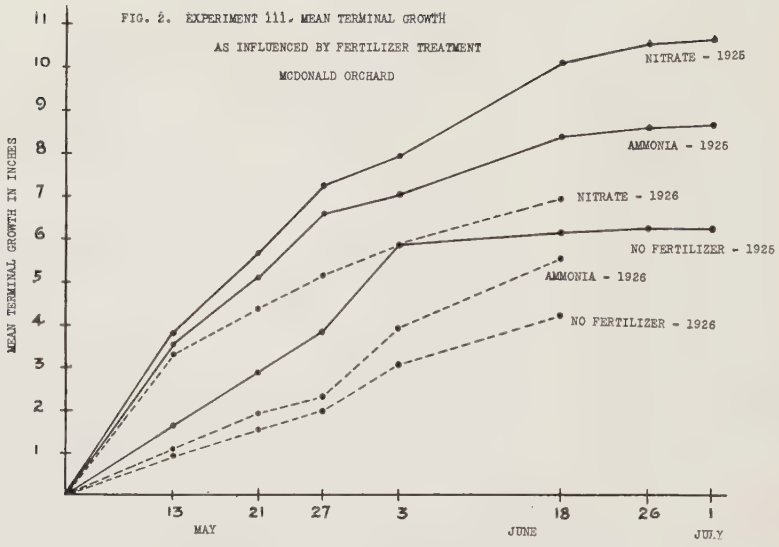
In Experiments I and II, in the Reynolds orchard at St. Marys, no significant differences in growth were found. Both terminal growth and trunk circumference measurements were taken.

Both spur and terminal growth measurements were obtained in the McDonald orchard (Experiment III) in 1925 and 1926. Ten terminals and ten spurs were tagged on each tree in the spring of 1925, and exact measurements of elongation were taken at regular intervals. Results are shown graphically in Figures 1 and 2. (Each point on the curves is the mean of 100 measurements.)



These curves show that nitrate of soda is a more quickly acting fertilizer than sulphate of ammonia where both were applied at bloom, but the effect of the latter extends over a longer period. However, total terminal growth at the end of each season was significantly greater where nitrate of soda was used.

In Experiment IV in the Robinson orchard only terminal growth measurements were taken. Results are shown in Table 2. No significant differences were obtained.



COMPARATIVE EFFECTS OF NITRATE OF SODA AND SULPHATE OF AMMONIA ON FRUITFULNESS

Records on fruit set were taken whenever conditions indicated that such data would yield valuable information on fertilizer effects. In taking these data several representative branches on each tree were tagged at blossoming time, and the number of flower clusters was counted. The number of fruit setting was determined later, generally before the June drop, and the percentage figured.

Total yield records (picked fruit and "drops") were taken for each tree in bushels (by volume rather than by weight measurements).

TABLE 2—*Experiment IV. Comparative effects of nitrate of soda and sulphate of ammonia on total terminal growth in feet of Black Twig in the Robinson (Burns place) orchard (1926-1930). Materials applied 2 to 3 weeks before bloom. Comparison by Student's method**

Pair	Total growth on trees receiving		d	d^2	Z= .50
	Sodium nitrate	Ammonium sulphate			
1	57	65	— 8	64	
2	53	37	+16	256	
3	61	72	—11	121	
4	72.5	80	— 7.5	56.25	Odds of
5	74.5	81	— 6.5	42.25	17.3:1 in
6	68	77	— 9	81	favor of
7	61	77	—16	256	ammonium
8	77	78	— 1	1	sulphate
9	76	83	— 7	49	
10	81	80	+ 1	1	
11	57	60	— 3	9	
12	71.5	63.5	+ 8	64	
13	58	57	+ 1	1	
14	35.5	68.5	—33	1089	

*In calculating odds, N equals degrees of freedom, or one less than the number of frequency classes. Odds must be at least 30:1 to be significant.

Set of Fruit

In Experiment I in the Reynolds orchard, records on set of fruit showed no consistent differences between sodium nitrate and ammonium sulphate when these were applied early. When applied at bloom, nitrate gave increases over sulphate of ammonia in all four years in which records were taken. Early applications of both fertilizers gave marked increases over the same fertilizers applied at bloom. This is shown in Table 3.

In Experiment II in the Reynolds orchard, fruit-set records were taken in 1926 and 1928. In 1926 odds were 3:1 and in 1928, 10:1 in favor of sulphate of ammonia — insignificant odds in all cases.

TABLE 3—*Experiment I. Comparative effects of nitrate of soda and sulphate of ammonia on set of fruit of Rome in the Reynolds orchard*

Treatment	Percent set			
	1923°	1924*	1925°	1926°
†Early sodium nitrate	16.4	38.8	8.3	7.3
Sodium nitrate at bloom	13.7	26.4	7.0	2.7
†Early ammonium sulphate	10.7	41.5	9.3	5.0
Ammonium sulphate at bloom	9.5	17.2	5.8	1.7

†2 to 3 weeks before bloom.
°After June drop.
*Before June drop.

TABLE 4—*Experiment III. Comparative effects of nitrate of soda and sulphate of ammonia on percent set of fruit in the McDonald orchard. Materials applied at bloom. Comparison by Student's method*

Pair	Set of fruit from trees receiving in 1925:		Set of fruit from trees receiving in 1926:	
	Sodium nitrate	Ammonium sulphate	Sodium nitrate	Ammonium sulphate
1	52.6	16.2	58.0	38.6
2	64.5	12.4	31.3	20.9
3	68.7	19.8	28.8	10.5
4	74.1	13.0	82.5	31.3
5	53.2	20.8	80.2	33.0
6	47.5	28.8	30.1	43.2
7	61.1	17.5	48.0	16.4
8	61.5	36.9	23.0	20.9
9	61.6	20.9	47.0	41.2
10	42.8	22.7	70.4	23.4
	Z = 2.83 Odds > than 9999:1 in favor of sodium nitrate		Z = 1.07 Odds 120:1 in favor of sodium nitrate	

In Experiment III at the McDonald orchard, set records were taken five weeks after bloom in 1925 and 1926. Odds in both years were significantly in favor of nitrate of soda. These results are shown in Table 4.

Records of set of fruit in the Robinson orchard (Experiment IV) were taken in 1926, 1928, and 1929. Frosts at bloom in 1927 and 1930 damaged the buds to such an extent that reliable records on set could not be taken. In 1926 these data showed odds of 6:1 in favor of nitrate of soda. In 1928 odds were 3:1 and in 1929, 7:1, both in favor of sulphate of ammonia — insignificant odds in all three years.

Yield of Fruit

In Experiments I and II in the Reynolds orchard yield records showed no significant differences where nitrate of soda and sulphate of ammonia were used.

In Experiment III in the McDonald orchard yield records show significant differences in favor of nitrate of soda (Table 5). The average annual tree yield of the check trees in this test was slightly more than one quarter bushel, showing that nitrogen was particularly needed in this soil.

TABLE 5—*Experiment III. Comparative effects of nitrate of soda and sulphate of ammonia on total yield in bushels of Jonathan in the McDonald orchard (1925-1927). Materials applied at bloom. Comparison by Student's method*

Pair	Total yield from trees receiving:		d	d^2	Z=1.0
	Sodium nitrate	Ammonium sulphate			
1	6.9	5.3	+1.6	2.56	
2	6.0	4.4	+1.6	2.56	
3	2.3	1.3	+1.0	1	
4	7.5	4.5	+3.0	9	Odds of
5	4.5	1.0	+3.5	12.25	89:1:1 in
6	5.4	5.8	— .4	.16	favor of
7	8.6	1.0	+7.6	57.76	nitrate
8	6.8	5.3	+1.5	2.25	of soda
9	2.6	3.3	— .7	.49	
10	7.4	4.5	+2.9	8.41	
Average annual tree yield	1.93	1.21	Average annual increase of nitrate of soda over sulphate of ammonia, 0.72 bushels		

Yields for the six-year period (1926-1931) in the Robinson orchard (Experiment IV) are shown in Table 6. Here there are significant differences in favor of sulphate of ammonia.

NITROGENOUS FERTILIZERS AND SOIL ACIDITY

Considerable attention in these experiments was given to the relative effects of nitrate of soda and of sulphate of ammonia on soil reaction. It has been known for a long time that sulphate of ammonia tends to make the soil acid, while nitrate of soda makes it alkaline. There are various theories to explain why sulphate of ammonia brings about an acid soil reaction. These theories are discussed by Pierre *(2)*. The generally accepted theory regarding nitrate of soda is that when it is added to the soil there is a greater absorption by the plant of the nitrate ion, leaving the basic sodium in the soil.

In Experiment I in the Reynolds orchard at St. Marys, soil acidity determinations were made in March, 1931, four years after the experiment had been discontinued. One boring was made 4 feet from each tree to a depth of 12 inches. Hydrogen-ion determinations of soil were paired and their significance was determined by Student's method. Results as seen in Table 7 show significantly greater acidity at 0 to 4 and 4 to 8 inches depth where sulphate of ammonia was used. Odds at 8 to 12 inches were least (25.5:1), indicating that

most of the acid effect of the sulphate of ammonia was near the surface.

TABLE 6—*Experiment IV. Comparative effects of nitrate of soda and sulphate of ammonia on total yield in bushels of Black Twig in the Robinson orchard (1926-1931). Materials applied 2 to 3 weeks before bloom. Comparison by Student's method*

Pair	Total yield from trees receiving:		d	d^2	Z= .6
	Sodium nitrate	Ammonium sulphate			
1	40.45	32.7	+ 7.75	60.0625	
2	38.1	29.9	+ 8.2	67.24	
3	47.5	62.1	—14.6	213.16	
4	73.4	74.9	— 1.5	2.25	Odds 32.4:1 in favor of ammonium sulphate
5	46.8	72.7	—25.9	670.81	
6	42.2	49.9	— 7.7	59.29	
7	62	77	—15	225	
8	76.65	73.9	+ 2.75	7.5625	
9	48.30	51.8	— 3.5	12.25	
10	49.3	53.5	— 4.2	17.64	
11	75.6	94.3	—18.7	349.69	
12	82.2	69.9	+12.3	151.29	
13	41.3	84.15	—42.85	1836.12	
14	40.4	59.7	—19.3	372.49	
Average annual tree yield	9.1	10.5	Average annual increase of sulphate of ammonia over nitrate of soda, 1.4 bushels		

Soil acidity determinations were made also in the Robinson orchard, with similar results. Computed in terms of lime requirement the average difference between the nitrate of soda and the sulphate of ammonia plots in this experiment is 1800 pounds of ground limestone per acre. These determinations were made in 1931 after five years of fertilization. It should be mentioned that these differences do not actually represent the acidifying action of the sulphate of ammonia. Nitrate of soda tends to make soils alkaline. Both reactions, opposite in effect, have therefore been going on during the course of the studies. Roughly speaking, the "souring" power of sulphate of ammonia is about twice the "sweetening" power of nitrate of soda.

DISCUSSION

In the studies reported in this bulletin sulphate of ammonia gave as good results as nitrate of soda in the two experiments in the Reynolds orchard when the applications were made early. Soil in this orchard is low in fertility and markedly acid in reaction. It is under such acid conditions that ammonia cannot be directly assimilated, according to Tiedjens and Robbins *(5)*, who grew one-year-old apple trees in sand at pH 5.4. Leaves were yellow in color. On the other hand, they found that trees supplied with calcium nitrate grew very well at this hydrogen-ion concentration. When the pH of the soil supplied with ammonium sulphate was increased to 8, the leaves turned green and growth was resumed. If ammonia is not assimilated directly by trees in an acid soil it must first be nitrified before being used. In an acid soil this goes on slowly. According to Waksman *(6)*, nitrification is stopped at a hydrogen-ion concentra-

tion of 4.4 to 4.8 pH. As shown in Table 7, some of the determinations of hydrogen-ion concentrations for this soil were as low as Waksman *(6)*, nitrification is stopped at a hydrogen-ion concentraman and Pierre, of this Station, it was found that considerable nitrification occurs in some soils at hydrogen-ion concentrations below even 4.0. Nitrification of the ammonia must have gone on in the Reynolds orchard, for fertilizer was put on the surface and little of the nitrogen could leach downward in the ammonia form and come in contact with the tree roots.

TABLE 7—*Experiment I. Comparative soil acidity effects produced by nitrate of soda and sulphate of ammonia in the Reynolds orchard*

Pair	Hydrogen-ion concentrations of soil under trees receiving:					
	Sodium nitrate	Ammonium sulphate	Sodium nitrate	Ammonium sulphate	Sodium nitrate	Ammonium sulphate
	Soil depth 0 to 4 inches		Soil depth 4 to 8 inches		Soil depth 8 to 12 inches	
1	5.0 pH*	4.5 pH	4.9 pH	4.6 pH	4.7 pH	4.9 pH
2	5.4	4.7	5.4	4.9	5.6	4.8
3	5.2	4.6	5.2	4.6	5.2	4.9
4	5.0	4.7	5.1	4.8	5.1	4.9
5	4.6	4.7	4.5	4.7	4.7	4.7
6	4.7	4.0	4.7	4.4	4.7	4.7
7	4.8	4.8	4.8	4.7	4.7	5.0
8	5.5	4.6	5.4	4.6	5.1	4.7
9	5.4	4.9	5.4	5.1	5.4	5.1
10	4.7	4.7	4.9	5.1	5.0	5.1
11	5.1	4.3	5.7	4.6	5.7	4.8
12	5.5	4.9	5.6	5.1	5.5	5.1
	Z = 1.45 Odds 1999:1 in favor of ammonium sulphate		Z = .98 Odds 174.6:1 in favor of ammonium sulphate		Z = .63 Odds 25.5:1 in favor of ammonium sulphate	

*A pH value of 7 indicates neutrality; lower values indicate acidity, and higher values indicate alkalinity.

When applications of fertilizers were made at bloom time, nitrate of soda was distinctly better than sulphate of ammonia in both the Reynolds orchard (Experiment I) and the McDonald orchard (Experiment III). Both soils were acid and under these conditions ammonia probably was not directly assimilated *(5)*. Nitrification changed the ammonia to nitrate — a form that could be used by the apple trees. Under spring conditions in an acid soil this change goes on slowly and trees do not get enough nitrogen in time to affect set, spur, and terminal growth as greatly as when nitrate of soda is applied. The slow release of this form of nitrogen is indicated by the data on duration of spur growth shown graphically in Figure 1. When both forms of nitrogen are applied early (10 to 15 days before bloom), nitrification seemingly goes on rapidly enough so that sufficient nitrates are absorbed by the trees and translocated to the fruiting parts in time materially to aid fruit set and wood growth.

In the Robinson orchard, where nitrate of soda and sulphate of ammonia have been applied 2 to 3 weeks before bloom, yield has been significantly greater where the latter has been used. The significance is not particularly marked, however, and it is questionable whether it indicates any distinct superiority.

Anthony *(1)* has found that trees in heavy bluegrass sods are

able to get little of the nitrogen when applied early as nitrate of soda or sulphate of ammonia because the grass gets most of it first. Sulphate of ammonia is much more likely to be absorbed by grass sods than nitrate of soda, because nitrogen in the form of ammonia will not be leached downward within the tree root zone until after nitrification has occurred. Under the generally adverse conditions of early spring this goes on slowly and in the meantime the ammonia is being utilized by the sod, since ammonia as well as nitrate can probably be assimilated directly by grasses. It is possible that this explains why Anthony got better results from nitrate of soda than from sulphate of ammonia in his early applications. This explanation is also suggested by Anthony. It may also explain Auchter and Schrader's *(4)* findings in Maryland, where they got better results the first few years from the use of nitrate of soda in a sod orchard. They give no data on soil reaction, but from the general description of the soil one would conclude that it was quite acid. It should be mentioned that the sod in the Reynolds orchard was very thin; it is therefore doubtful that it got most of the nitrogen. On the other hand, the sod in the McDonald orchard was a heavy bluegrass. This may be a factor in the poor showing of sulphate of ammonia in this experiment, although it is probable that sulphate of ammonia would have shown up better if the fertilizers had been applied early.

If cover crops, particularly leguminous ones, are to be grown, continued use of sulphate of ammonia will make it difficult to do so unless the soil is limed. According to Pierre *(3)*, for every ton of ammonium sulphate a little over a ton of ground limestone should be used to counteract acidity. Since the cost of a unit of nitrogen in sulphate of ammonia is little more than one half the cost in nitrate of soda, the apple orchardist can well afford to add lime.

SUMMARY

Four fertilizer experiments comparing nitrate of soda and sulphate of ammonia with apple trees are reported in this bulletin. A brief review of each experiment with the results obtained follows:

Experiment I was started in 1922 with 32-year-old Rome trees in the Reynolds orchard at St. Marys, Pleasants County. This report covers the period from 1922 to 1927. Early applications of both fertilizers were superior to those made at bloom. Nitrate of soda was superior to sulphate of ammonia when both were applied at bloom. When applied 10 to 15 days before, there were no significant differences in results obtained from the two fertilizers.

Experiment II was begun in 1926 with 36-year-old Rome trees in the same orchard. Fertilizers were also applied 10 to 15 days before bloom. No differences in growth or yield were obtained.

Experiment III was begun in 1925 on 9-year-old Jonathan trees in the McDonald orchard at Darkesville in Berkeley County. Fertilizers were applied at bloom time. Nitrate of soda was significantly superior to sulphate of ammonia in both growth and fruitfulness.

Experiment IV was begun in 1927 on 25-year-old Black Twig trees in the Robinson orchard, Jefferson County. Fertilizers were applied 2 to 3 weeks before bloom. No differences in growth were observed between trees fertilized with nitrate of soda and those fertilized with sulphate of ammonia. Significant differences in yield were obtained, the trees fertilized with sulphate of ammonia yielding more. The significance, however, was not particularly marked.

Soil acidity determinations were made in Experiments I and IV. Sulphate of ammonia tended to make the soil acid. In Experiment IV, after fertilizer applications had been made for five years, the difference in lime requirement between nitrate and ammonia plots averaged 1800 pounds per acre.

NITROGEN FERTILIZER RECOMMENDATIONS

The choice between the use of nitrate of soda and sulphate of ammonia in the apple orchard should be determined by their relative cost in terms of nitrogen units. At this time a unit of nitrogen in sulphate of ammonia costs little more than one half what it costs in nitrate of soda, and is equally valuable as a fertilizer if applied two to three weeks before bloom. To insure full value from sulphate of ammonia it should be applied at least two weeks before bloom, and should be worked into the soil where early cultivation is being practiced. In figuring comparative costs of the two nitrogen carriers it should be borne in mind that eventually lime must be applied to correct the acidity of the sulphate of ammonia particularly if legume cover crops are grown. In such cases the lime requirement should be determined and the amount needed to correct acidity should be applied.* Addition of lime will not only help the cover crop but also tend to make the ammonia more quickly available.

*The Agricultural Experiment Station will determine lime requirements for West Virginia orchards free of charge. In taking soil samples in an orchard where sulphate of ammonia has been applied to the soil under the trees, proceed as follows: On each soil type or area given the same treatment in the past, take a boring of soil to a depth of 6 inches under 10 to 12 different trees. Thoroughly mix the soil from these borings. Take a pint sample of this. Prepare a second sample by making the same number of borings in the area beyond the spread of tree branches where the sulphate of ammonia has not been put on. Mail samples in tight containers to the Department of Agronomy at Morgantown. If an auger is not available for making the borings, a perpendicular 6-inch slice of soil can be removed with a trowel or spade.

LITERATURE CITED

1. Anthony, R. D. Sulphate of ammonia and nitrate of soda in a sod orchard. Penn. Agr. Exp. Sta. Bul. 249. 1930.
2. Pierre, W. H. Nitrogenous fertilizers and soil acidity: I. Effect of various nitrogenous fertilizers on soil reaction. Jour. Am. Soc. Agron. 20:3:254-269. 1928.
3. ————. Nitrogen fertilizers and soil acidity. Mountaineer Grower: 3:24:64-68. 1932.
4. Schrader, A. L. and E. C. Auchter. The comparative effects of different nitrogen fertilizers on bearing apple trees low in vigor. Proc. Am. Soc. Hort. Sci. 24:229-233. 1927.
5. Tiedjens, V. A. and W. R. Robbins. The use of ammonia and nitrate nitrogen by certain crop plants. N. J. Agr. Exp. Sta. Bul. 526. 1931.
6. Waksman, S. A. Microbiological analysis of soils as an index of soil fertility: V. Methods for the study of nitrification. Soil Sci. 15:241-260. 1923.

BULLETIN 253 NOVEMBER, 1932

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

Inheritance Studies of the Reaction of Selfed Lines of Maize to Smut (Ustilago zeae)

by M. M. HOOVER

THE COMMON OR BOIL SMUT, *Ustilago zeae*, has nearly a world-wide distribution and is easily recognized by characteristic smut masses or tumors which may appear on any of the aerial parts of the plant. It is a curious fact that although corn is native to America and smut undoubtedly has occurred here for centuries, the disease was first described by the French botanists, Bonnet *(13)*† in 1754, and Aymen in 1760. Schweinitz in 1822 was the first to describe the disease in the United States.

Up to about the middle of the 19th century corn smut was believed to be a physiological disturbance due to "too great an abundance of sap which in rich land is carried towards certain portions of the plant" (Tillet). This concept was destroyed by the discovery of the parasitic nature of the fungus by Kuehn, Brefeld, and others who established the fact that this fungus was not seed-borne, as is the case with most of the cereal smuts, but that infections are local and can occur in any actively growing tissues. It remained for Stakman and his co-workers to point out the presence of physiologic forms of smut and demonstrate that the pathogene is predominantly heterothallic, the fusion of lines of opposite sex being prerequisite to infection.

The mature smut tumor consists of a thin membrane derived from host tissue which at first is gray but later becomes dark in color. The membrane encloses a mass of spores (chlamydospores), fibrovascular bundles, and parenchyma cells of the host plant. These

*The writer takes pleasure in acknowledging his indebtedness to Dr. R. A. Emerson of Cornell University for materials and helpful suggestions, and to Dr. R. J. Garber of West Virginia University for the encouragement and friendly criticism during the progress of this investigation. The writer wishes to express his appreciation to Dr. L. M. Peairs for his suggestions in the preparation of this manuscript and to thank his colleagues who have so willingly collaborated in this work.

†Reference by number is to "Literature Cited," pages 31 and 32.

spores are set free by the rupture of the membrane and may be carried by wind, on refuse, or by other agencies to suitable locations, where they germinate.

The mature chlamydospores are diploid. On germination they normally produce a pro-mycelium in which reduction division apparently occurs. The sporidia are uninucleate and grow by budding in a typically yeast-like fashion; thus the progeny of a single sporidium should constitute a clonal line. This habit of growth and relative ease with which pure sporidial lines can be isolated makes smut a very desirable material for the study of mutations.

Stakman *(33, 34, 35)* and his co-workers have demonstrated that most monosporidial lines alone cannot cause normal infection in the host. It therefore becomes necessary to test a combination of forms. Culture media have not proved satisfactory in this work for, although monosporidial lines will grow profusely in culture, it appears that diplonts can be produced only in the living host.

In recent studies on rate of mutation of smut from different geographical locations, Stakman has shown that the mutation rate is extremely high in certain monosporidial lines. This is of particular interest since West Virginia strain A-8 was found to be one of the most prolific, giving 162 distinct mutants during the course of one year. Because of this rapid mutation rate and the resulting hybridization that might follow, the number of physiologic forms present in the West Virginia corn nursery must be exceedingly high. There seems to be little doubt about the presence of physiologic forms and the hybridization of these forms under natural conditions. Any improvement of corn by breeding methods should take into account the fact that physiologic strains do exist and that the probability is that new forms may arise from time to time.

The annual loss due to smut in the United States is variable and rather difficult to measure, but an estimate of between two and three percent by the Plant Disease Reporter *(29)* of the United States Department of Agriculture is probably as good a figure as is available at the present time. Under certain conditions this loss may be much higher, and figures ranging from five to twenty percent are frequently reported for some states. Careful re-survey work carried on at the Minnesota Experiment Station *(18)* indicates that the figures given by the Plant Disease Reporter are somewhat lower than the actual field conditions indicate. This loss due to smut is most apparent in areas where corn is grown for market, since the presence of smut makes the ear unfit for canning or table consumption.

There is no close agreement among investigators as to the effect of environmental factors on the prevalence of smut. Many of the earlier workers, among them Hitchcock and Norton *(14)* as well as Selby and Hickman *(32)*, felt that any conditions which stimulate the host to vigorous growth or increased succulence seem to increase the chances for infection. Coffman, Tisdale, and Brandon *(4)*

making observations at Akron, Colorado, state that smut is most prevalent during dry seasons. This is thought to be due in part to better survival and dissemination of chlamydospores as well as to the higher temperatures that occur during dry seasons. Immer and Christensen *(18)* at Minnesota also found that dry weather conditions tend to give a heavy smut infection. Potter and Melchers *(30)* in reporting studies on the ecological relations of smut state that the stage of development of the host is more important than the time of season. Leaf, tassel, shoot, and basal nodes or suckers represent the stages in the development of a plant when meristematic activity is at a maximum and infection is most likely to occur. Moisture is not a limiting factor for the fungus so long as there is sufficient for host development. Tisdale and Johnston *(36)* working with seedlings in the greenhouse were able to get a heavy infection only when humidity was high and a temperature of 80° - 95° F. was maintained.

Considerable data have been accumulated by different investigators as regards the effect of smut on yield. Garber and Hoover *(9)* in working with the F_1 hybrids between selfed strains found that barrenness was greatly increased among the smutted plants, but that if a plant, although infected with smut, is able to produce an ear, the yield from such a plant was not materially less than from adjacent non-infected plants. These observations were more marked when groupings of the smutted plants were made according to the region of the plant where infection occurred. Plants with tassel infection produced significantly greater yields of shelled corn than uninfected plants within the same strain. Recent work by Kyle *(24)*, where studies of the relation between vigor of the corn plant and its susceptibility to smut were reported, indicate that the more vigorous plants in general are those that have the highest percentage of smut. Kyle points out the danger in the procedure of most plant breeders who select within their selfed lines of corn only those strains that are smut free. This selection he feels will in time tend to eliminate not only the smut-susceptible strains but also those strains that are potentially high in yield. On the other hand Immer and Christensen *(16)* at Minnesota, as well as Jorgensen *(22)* at Ohio, found that smut tended to decrease the yield and that smut infections located above the ear tend to reduce the yield significantly more than did galls below the ear.

Many plant breeders have been able to isolate selfed lines of maize that show differential susceptibility to smut. The behavior of certain crosses between high and low susceptible lines is such as to show that resistance or susceptibility represents strain characteristics. At the time the present work was undertaken, the writer was not aware of the inheritance studies that were being conducted by Dr. Immer *(17)* at Minnesota. This investigation parallels the work of Dr. Immer rather closely in certain phases and it is interesting to compare the similarity of conclusions regarding the genetic

aspects of smut inheritance. The following report is an attempt to demonstrate the inheritance of smut reaction in crosses between certain selfed strains and to show the relation between smut reaction and certain known heritable characters.

MATERIALS AND METHODS

The data reported in this paper were obtained from studies of the smut reaction of certain selfed lines of maize that were being carried as a part of the general corn breeding project at the West Virginia Agricultural Experiment Station. During the past ten years more than 200 selfed strains of maize have been grown under smut-epiphytotic conditions and careful notes recorded for the smut reaction of each plant during the season. The general plan has been to grow each strain in duplicated single row plats, each plat consisting of 50 single plant hills spaced 18 inches apart in the row. The smut epiphytotic was created by scattering smut-contaminated horse manure three times during the growing season. The first application was made when the plants were approximately knee high; this treatment was followed at two-week intervals by the second and third applications.

It was found convenient to take the smut notes on mimeographed sheets, each one of which was ruled and numbered from one to fifty, and divided into columns to indicate the place of appearance of the smut boil on the plant, such as tassel, neck (region between tassel and top leaf of plant), leaf, ear, below ear, and base. Sizes of smut boil were indicated by the following numeral grades: No. 1 (size of grain of wheat), No. 2 (size of marble), No. 3 (size of walnut), and No. 4 (larger than walnut). Three men worked together in taking the smut notes. One individual acted as recorder while the other two (one on each side of the row) carefully examined the plants for smut. In this manner each plant was carefully examined, and the amount and place of smut recorded. Smut data were usually taken at three dates: the first shortly after the plants had finished silking, the second some three weeks later but before the leaves had begun to shatter, and the third and last, at the time of husking. Attention was given chiefly to the prevalence of ear smut at the third time.

Seed from a strain of corn known to be rather highly susceptible was planted in every tenth row throughout the nursery to serve as a check upon the extent and uniformity of the smut epiphytotic produced. The amount of smut varied somewhat from year to year but there was no year in which a "satisfactory" smut epiphytotic failed to appear. The range of infection of the susceptible checks was found to be from 40 to 80 percent, with an average of 62 percent smutted plants for a nine-year period. Selection was practiced among the selfed lines of corn with the hope of establishing certain lines that were immune to smut.

SMUT REACTION OF CERTAIN SELFED LINES OF MAIZE, AND CROSSES BETWEEN THESE SELFED LINES

The results of the smut reaction of certain selfed lines of maize over a period of years are given in Table 1. It will be noticed that selfed lines differ in regard to the evident amount of smut infection so that it would be a relatively easy matter to isolate high-infection and low-infection selfed lines. There is also a marked tendency for certain lines to show susceptibility in a particular part of the plant. Thus one can identify tassel and base strains as indicated in Table 1.

The inheritance studies deal with crosses among these West Virginia strains as well as crosses between these strains and genetic linkage testers of unknown smut reaction. It is in order here to point out that the tassel strain has shown fairly high susceptibility and that over 80 percent of the smut observed in these selfed plants is located in the tassel.

The base strain is highly susceptible. On the average, over 75 percent of all plants were smutted, and over 80 percent of all the

TABLE 1—*Smut reaction of certain selfed lines of maize with number of plants, place, and percentage of smut infection*

Name of strain	Year	Number of plants	Place of infection						Percent	
			Tassel	Neck	Leaf	Ear	Below ear	Base		
Tassel	1924	23	8	..	..	..	..	1	39.1	
	1925	87	14	..	..	..	..	3	19.5	
	1926	94	38	..	..	..	2	..	42.6	
	1927	86	27	..	..	..	..	..	31.4	
	1928	68	22	..	1	4	1	..	41.2	
	1929	146	91	1	..	6	4	..	69.9	
	1930	172	17	..	1	1	9	..	16.3	
	1931	188	110	1	7	10	7	8	76.1	
	Total	864	83.0	0.5	2.3	5.3	5.8	3.0	45.6	ave.
Base	1926	50	..	..	5	5	13	6	58.0	
	1929	49	..	7	2	6	4	7	53.1	
	1930	102	..	..	..	7	62	6	73.5	
	1931	142	6	1	..	1	87	35	91.5	
	Total	343	2.3	3.1	2.7	7.3	63.8	20.8	75.8	ave.
Yellow-resistant	1922	52	..	..	..	..	..	..	0.0	
	1923	23	1	..	..	..	..	..	4.3	
	1924	24	..	..	..	..	..	..	0.0	
	1925	91	..	..	..	..	..	..	0.0	
	1926	94	..	..	1	..	..	..	1.1	
	1927	96	..	..	..	..	..	1	1.0	
	1928	94	..	..	..	1	..	1	2.1	
	1929	149	..	..	..	..	1	..	0.7	
	1930	177	..	1	..	..	2	2	2.8	
	1931	131	6	..	..	1	..	1	6.1	
	Total	931	..	..	..	..	..	..	2.0	ave.
White-resistant	1922	49	2	..	..	..	..	..	4.1	
	1923	21	..	..	..	..	..	..	0.0	
	1924	19	..	..	..	..	..	..	0.0	
	1925	80	2	..	..	..	..	..	2.5	
	1926	96	..	..	..	..	1	..	1.0	
	1927	97	1	..	..	..	..	..	1.0	
	1928	94	3	1	..	2	..	..	6.4	
	1929	142	..	..	..	1	..	..	0.7	
	1930	162	..	1	..	..	..	..	0.6	
	1931	200	7	..	1	1	..	..	4.5	
	Total	960	..	..	..	..	..	..	2.4	ave.

smutted plants were smutted in the lower region of the plant. Base and below-ear infection are considered together in the discussion of smut reaction.

Table 1 does not take into account the secondary infections that may be present in a given plant, but classifies a plant in the column which represents the position of the largest smut boil. Table 2 has been constructed to show these secondary smut infections and reveals a very distinct difference between the tassel and base strains which is not evident from a study of Table 1 alone. For example, Table 1 classifies 67 smutted plants in categories other than tassel; Table 2 shows that 29 of these 67 (or 43 percent) are also infected in the tassel. This further emphasizes the fact that this strain has a pronounced predisposition for smut susceptibility in the tassel. The places of secondary infection in the base strain show a more general distribution. Of the 220 plants that fall in the base and the below-ear primary classes, only 69 (31.4 percent) also show secondary infection in this same region, while 33 plants (15 percent) show secondary infections in the tassel. In considering the crosses between these strains it may be well to have this smut relation of the parents in mind when an interpretation of the observed data is attempted.

TABLE 2—*Multiple smut infection for all plants of the tassel and base strains*

	Primary infection		Secondary infection					
	Place	No. of plants	Place and number of plants					
			Tassel	Neck	Leaf	Ear	Below ear	Base
Tassel strain	Tassel	327	0	1	2	0	1	0
	Neck	2	1	0	0	0	0	0
	Leaf	9	2	0	0	0	1	0
	Ear	21	14	0	0	0	1	0
	Below ear	23	8	0	0	0	0	0
	Base	12	4	0	0	0	0	0
Base strain	Tassel	6	0	0	0	0	0	0
	Neck	8	0	0	1	0	1	1
	Leaf	7	0	0	0	0	0	0
	Ear	19	1	1	1	0	4	3
	Below ear	166	28	5	14	6	0	66
	Base	54	5	4	8	1	3	0

The yellow and white-resistant strains show a marked resistance to smut when their reaction over a period of years is studied. These plants did not show any secondary infection and are therefore not presented in such a table. The smutted plants that were observed in the yellow-resistant strain show rather general distribution of the place of infection. In the white-resistant strain, which shows about the same average infection as the yellow-resistant, there seems to be a tendency for infection in the smutted plants to be limited to the tassel since 15 out of a total of 23 plants (or 65 percent) show tassel infection.

Table 3 shows the smut reaction of the F_1, F_2, and backcross plants obtained from crosses between West Virginia tassel, base,

yellow-resistant, and white-resistant selfed strains. The original crosses were made in 1929 and the F_1 plants were grown in 1930. Certain of these F_1 plants were backcrossed to their respective parents while others were self-pollinated. The backcross or the F_2 plants were grown in 1931 and furnish the bulk of the data in Table 3. Wherever possible, data were obtained from backcross in preference to F_2 plants since it was felt that fewer plants would be required to give the necessary data for genic analysis.

TABLE 3—*Smut reaction of the F_1, F_2, and backcross plants from crosses between certain West Virginia selfed lines*

Description of parents	Number of plants	Place of infection						Percent infection	Diff.
		Tassel	Neck	Leaf	Ear	Below ear	Base		P. E.
(Tassel x base) F_1	101	5	0	3	2	14	5	28.7	
(Base x tassel) F_1	113	10	0	1	0	29	7	41.6	4.12
(Tassel x base) F_2	93	27	1	3	5	9	2	50.5	
(Base x tassel) F_2	41	15	4	0	0	0	2	51.2	0.13
(Tassel x base) x base	56	0	1	5	3	25	11	80.4	
(Base x tassel) x base	92	0	1	15	2	45	6	75.0	1.51
(Base x tassel) x tassel	18	10	0	2	0	3	0	83.3	
(Tassel x yel.-res.) F_1	125	17	0	2	1	7	1	22.4	
(Yel.-res. x tassel) F_1	45	6	0	0	0	5	4	33.3	2.3
(Tassel x yel.-res.) F_2	67	26	0	0	0	7	0	49.2	
(Tassel x yel.-res.) x tassel	5	4	0	0	0	0	0	...	
(Yel.-res. x tassel) x tassel	79	27	0	0	0	8	4	49.4	
(Tassel x yel.-res.) x yel.-res.	60	9	1	2	0	4	4	33.3	
(Yel.-res. x tassel) x yel.-res.	84	5	2	1	0	6	3	20.2	3.2
(Tassel x white-res.) F_1	120	12	0	3	1	3	0	15.8	
(Wh.-res. x tassel) F_1	66	4	0	0	0	4	1	13.5	0.55
(Tassel x wh.-res.) F_2	75	24	3	2	2	2	1	45.3	
(Wh.-res. x tassel) F_2	100	5	1	1	2	3	1	13.0	8.32
(Tassel x wh.-res.) x wh.-res.	46	8	0	0	0	0	0	17.4	
(Wh.-res. x tassel) x wh.-res.	98	0	0	0	0	1	0	1	4.35
(Base x yel.-res.) F_1	120	0	2	1	0	16	3	18.3	
(Yel.-res. x base) F_1	111	0	5	2	1	17	5	27.0	3.06
(Base x yel.-res.) x base	93	0	0	3	0	54	13	75.3	
(Yel.-res. x base) x base	78	5	2	3	0	28	18	71.8	1.02
(Base x yel.-res.) x yel.-res.	94	7	0	0	1	5	3	17.0	
(Yel.-res. x base) x yel.-res.	97	4	6	2	5	3	0	20.6	.92
(Base x wh.-res.) F_1	55	2	0	0	0	1	0	5.4	
(Wh.-res. x base) F_1	68	1	1	2	1	3	0	11.7	3.06
(Wh.-res. x base) F_2	96	2	6	7	1	9	2	28.1	
(Base x wh.-res.) x base	96	6	2	2	1	24	11	47.9	
(Base x wh.-res.) x wh.-res.	109	7	1	1	0	1	0	9.2	
(Wh.-res. x base) x wh.-res.	93	3	2	0	0	1	0	6.4	1.64
(Yel.-res. x wh.-res.) F_1	89	4	1	0	0	0	0	5.6	
(Wh.-res. x yel.-res.) F_1	65	0	0	0	0	0	0	0	2.95
(Yel.-res. x wh.-res.) x yel.-res.	83	1	0	0	0	2	0	3.6	
(Wh.-res. x yel.-res.) x yel.-res.	87	2	0	1	0	1	1	5.7	1.29
(Yel.-res. x wh.-res.) x wh.-res.	65	0	0	0	0	0	0	0	
(Wh.-res. x yel.-res.) x wh.-res.	70	0	0	0	0	0	0	0	
(Wh.-res. x yel.-res.) x wh.-res. selfed F_2	49	0	0	0	0	0	0	0	
(Wh.-res. x yel.-res.) x yel.-res. selfed F_2	53	0	0	0	0	1	0	1.9	1.51

Tassel x Base

The F_1 plants from the cross (tassel x base) show 28.7 percent smut, with 65.5 percent of the smutted plants infected in the basal region. The smut reaction of the F_1 plants from the cross (base x tassel) gave a total of 41.6 percent smut, with 76.6 percent of the smutted plants infected in the basal region. The F_1 plants were grown during 1930, a very dry season, and the wide differences in total amount of smut observed in the reciprocal crosses may be due in part to the uneven smut epiphytotic that prevailed. The plants from both direct and reciprocal F_1 crosses showed a similar behavior in the region of the plant where infection occurred. It is also apparent that the "base" strain shows greater influence on the place of infection in the F_1 plants than the "tassel" parent.

The F_2 plants from the cross (tassel x base) show 50.5 percent of the plants smutted. This is essentially the same as the smut reaction of the F_2 plants from the (base x tassel) cross, which gave 51.2 percent smutted F_2 plants. The majority of the F_1 plants from these crosses showed basal infection, whereas in the F_2 plants from the same crosses most plants are infected in the tassel. The amount of smut was found to be intermediate between that of the two parent strains.

Backcross plants obtained from the cross (tassel x base) x base gave 80.4 percent infected plants, and over 80 percent of the smutted plants showed basal infection. The backcross plants obtained from the cross (base x tassel) x base showed a total of 78.5 percent infection, with 74 percent of the infected plants showing smut boils in the basal region of the plants. It is clearly shown here that the base strain is a highly susceptible one and that, within any genotype, the tendency for basal infection is greatly increased by the recurrent use of this strain.

Backcross plants obtained from the cross (base x tassel) x tassel gave a smut infection of 83.3 percent, with two-thirds of the smutted plants showing tassel infection. This indicates that when the "tassel" strain is used as the recurring parent there is a tendency to increase the tassel infections in the progeny. It is unfortunate that there were so few plants from this cross.

Tassel x Yellow-Resistant

The F_1 plants obtained from the cross (tassel x yellow-resistant) gave 22.4 percent smut, while the reciprocal F_1 (yellow-resistant x tassel) gave 33.3 percent smutted plants. Most of the smutted plants were infected in the tassel. The differences in the amount of smut in the direct and reciprocal F_1 are wide but are probably not significant. The small number of plants obtained in the cross (yellow-resistant x tassel) may account for the differences in the observed percentage.

The F_2 plants obtained from the cross (tassel x yellow-resistant) gave a total infection of 49.4 percent. Nearly 79 percent of these

smutted plants were infected in the tassel. This, it will be recalled, was also found to be the condition in the F_2 plants from the (tassel x base) cross.

The backcross plants obtained from a cross of (yellow-resistant x tassel) x tassel gave a total smut infection of 49.4 percent, with nearly 70 percent of the smutted plants showing infection in the tassel.

The backcross plants obtained from crossing the F_1 back on the yellow-resistant parent showed less smut than when the cross was made back to the tassel parent. These results are in keeping with those previously obtained and show that the recurrent parent usually dominates the smut reaction in backcross material.

Tassel x White-Resistant

The F_1 plants obtained from the cross (tassel x white-resistant) gave 15.8 percent smut. Most of the smutted plants were infected in the tassel. The reciprocal F_1 plants obtained from the cross (white-resistant x tassel) gave a smut reaction of 13.5 percent. It will be recalled that over a period of years there was found but a slight difference in the amount of smut observed in the yellow-resistant and white-resistant selfed strains. In crosses involving these two strains, the white-resistant parent seems to show a great deal more resistance than does the yellow-resistant parent. In the case at hand the F_1 (tassel x yellow-resistant) gave smut percentages of 22.4 and 33.3 for the direct and reciprocal F_1 plants, whereas the comparable crosses (tassel x white-resistant) with the white-resistant parent gave 15.8 percent and 13.5 percent smut infection. This greater efficiency of the white-resistant over the yellow-resistant parent can be observed in every cross where a direct comparison is possible.

F_2 plants obtained from the cross (tassel x white-resistant) gave a percent smut infection of 45.3. This is based on a population of 75 plants and represents an exceptionally heavy infection for plants where the white-resistant strain was one of the parents. The F_2 plants obtained from the cross (white-resistant x tassel) gave a smut infection of 13.0 percent, which is in keeping with the expected results.

Backcross plants obtained from the cross (tassel x white-resistant) x white-resistant gave a smut infection of 17.4 percent as compared to the reciprocal cross (white-resistant x tassel) x white-resistant with a smut infection of 1 percent. With the one exception noted, the smut reaction of all crosses involving the white-resistant parent have given plants that show rather high resistance to smut.

Base x Yellow-Resistant

F_1 plants obtained from the cross (base x yellow-resistant) gave a smut infection of 18.3 percent, with over 85 percent of the smutted plants showing basal infection. The F_1 plants obtained from the cross (yellow-resistant x base) show a smut infection of 27.0 per-

cent, with over 73 percent of the smut boils appearing in the basal region.

Backcross plants obtained from the cross (base x yellow-resistant) x base show a total of 75.3 percent smut, with over 90 percent of the smutted plants infected in the basal region. The reciprocal cross of (yellow-resistant x base) x base gave a total of 71.8 percent smut, with over 82 percent of the plants with basal infections. These backcross results are similar in amount and place of infection and do not show a difference of statistical significance.

Backcross plants obtained from the cross (base x yellow-resistant) x yellow-resistant gave a smut infection of 17 percent. No tendency was noted for the boils to appear in any particular part of the infected plants. The backcross plants from the cross (yellow-resistant x base) x yellow-resistant gave a smut infection of 20.6 percent. The interesting feature about these results lies in the comparison of the backcrosses. When the recurrent parent was the "yellow-resistant" instead of the "base", the percent smut infection was reduced from 75.3 and 71.8 for the direct and reciprocal crosses to 17.0 and 20.6 percent, respectively. This indicates that the yellow-resistant parent is capable of contributing a comparatively high degree of resistance to its progeny. It is equally apparent that, with the recurrence of the "base" strain in the genotype, the total amount of infection is greatly increased and the likelihood of the occurrence of smut on the basal part of the plant is also greatly increased.

Base x White-Resistant

Data obtained from crossing the West Virginia "base" strain x white-resistant are comparable to the same crosses made with the yellow-resistant strain, except that the progeny of white-resistant crosses seems to be even more resistant than that of the yellow-resistant. A comparison of the values of smut reported in the last column of Table 3 for the comparable crosses clearly indicates these differences.

Yellow-Resistant x White-Resistant

The observed behavior of the yellow-resistant and white-resistant strains when crossed with tassel selfed line and base selfed line leads one to expect to find but little smut when these strains are themselves intercrossed. This is indeed the case, as the data in Table 3 indicate. Even here, however, it is evident that the white-resistant parent is the one contributing the greater resistance to any given cross. The F_2 data indicate the possibility of the isolation of types from the crosses between yellow-resistant and white-resistant strains that are still more highly resistant to smut and that show considerable promise as foundation stock for further breeding work.

From a study of data presented in Tables 1, 2, and 3 it becomes evident that selfed strains differ sharply in regard to amount and

position of smut infection. Although distinct differences are apparent for the different strains, the behavior of any one remains remarkably uniform over a period of years. This would suggest that the basis for the differences observed is due to variations in genotypes and therefore heritable.

From the evidence obtained from strain intercrosses that differ in respect to susceptibility and place of infection, it may be clearly demonstrated that the susceptibility to smut infection is transmitted from parent to offspring. The fact that no distinct observable ratios can be identified in the backcross or the F_2 progeny from a given cross is some evidence that several factors play a part and are responsible for the observed differences. There is little doubt that the "resistant" parents as well as the "base" and "tassel" strains are able to transfer their own peculiarities to their offspring; this was particularly evident from a study of backcross data. Furthermore, this resistance or susceptibility is probably physiological, since no morphological differences were apparent which could account for the smut reaction observed in the parents or offspring.

GENETIC ANALYSIS OF WEST VIRGINIA SELFED STRAINS, AND SMUT REACTION OF CROSSES WITH KNOWN GENETIC TESTERS

The observations reported in Section III led to an attempt to determine, if possible, any linkage relation that might exist between the factor or factors responsible for smut inheritance and other known genetic factors. Accordingly, crosses were made between the different West Virginia selfed lines and linkage testers which carried known genetic factors, to see if evidence for the inheritance of smut reaction could be obtained by observing the inheritance of these known factors in relation to smut infection. With this study in mind genetic material representing nine linkage groups was assembled, and appropriate crosses were made.

West Virginia tassel, base, yellow-resistant, and white-resistant strains were crossed with the appropriate linkage tester and smut notes recorded for the F_1 plants as well as for the backcross and F_2 segregating progenies. In presenting the data obtained, the results of crossing each linkage tester with the West Virginia strains are given and discussed separately. It should be pointed out here that the linkage testers used were of unknown behavior regarding smut reaction; however, such evidence as has been accumulated during the time these testers have been grown in West Virginia indicates that all of them are rather highly susceptible. This suggests that the most critical evidence on the inheritance of smut reaction should be sought in the progeny from crosses involving the resistant strains.

West Virginia tassel, base, and yellow-resistant strains are all yellow in color, while the white-resistant lacks the yellow endosperm. These strains were isolated from Leaming, Lancaster Sure Crop,

Reid's Yellow Dent, and Boone County White varieties, respectively. As a result of crosses made with the genetic testers used, it was found that all four West Virginia strains lacked dominant C and R of the aleurone series but were normal in regard to all other genetic factors for which tests were made.

*Linkage Group I**

The genetic tester used to test Linkage Group I was known to be of the following genotype: AA CC RR shsh wxwx Prpr. West Virginia tassel, base, yellow-resistant, and white-resistant strains were each pollinated with the shrunken-waxy tester. The crossed seed was characteristic of a purple aleurone over a yellow endosperm, except for the ears resulting from the cross with white-resistant, which gave seed light purple in color. Seeds planted from the crossed ears gave smut reaction for the F_1 plants during the 1930 growing season as shown in Table 4.

TABLE 4—*Smut reaction of the F_1 plants from a cross of certain selfed strains and a shrunken-waxy tester*

Description of parents	No. of plants	Place of infection						Percent infection
		Tassel	Neck	Leaf	Ear	Below ear	Base	
(Tassel x sh-wx) F_1	46	1	0	0	0	2	0	6.5
(Base x sh-wx) F_1	26	0	0	1	1	4	2	30.8
(Yel.-resist. x sh-wx) F_1 ..	104	2	0	0	0	0	0	1.9
(Wh.-resist. x sh-wx) F_1 .	112	0	0	0	0	0	0	0

Certain of the F_1 plants were backcrossed to the shrunken-waxy tester while others were self pollinated. Table 5 gives the color and endosperm classes of the ears obtained. The counts entered in the table are the totals obtained from two or more ears from each backcross or each F_2. The combined data obtained from the backcrosses indicate a crossover value of 16.2 percent between the shrunken-waxy loci. This percentage was used in calculating the theoretical numbers in both backcross and F_2 populations. P values range from 0.37 to 0.56 for the F_2 ears recorded and from 0.18 to 0.37 for the backcross ears. The observed numbers approached the expected class values so closely that the observed deviations might be expected through chance more than twice in five trials (P equalling 0.45) for the F_2 ears, and more than twice in seven trials (P equalling 0.28) in the backcross ears. Plantings were made of each of the color and endosperm classes and careful field notes recorded on the smut reaction of each plant during the growing season of 1931. Data obtained are presented in Table 6.

It will be noted that the data are listed to show the parentage of any given material and that comparisons are made only between plants of a given endosperm and genotypic constitution. Only seeds obtained from backcross ears were used in these plantings.

*The order of presenting the data for different linkage groups is that followed in the mimeographed "Summary of Linkage Groups in Maize" prepared by the Department of Plant Breeding of Cornell University, 1929 *(7)*.

TABLE 5—*Color and endosperm condition of backcross and F_2 ears obtained from crossing certain selfed strains and a shrunken-waxy tester*

Description of parents	*	Purple				Red				Yellow				White				X^2 and P values
		ShWx	Shwx	shWx	shwx	ShWx	Shwx	shWx	shwx	ShWx	Shwx	shWx	shwx	ShWx	Shwx	shWx	shwx	
(Tassel x sh-wx) F_2	O	118	27	26	49					130	14	10	13					X^2= 7.6014
	C	125	20	22	50					135	10	7	17					P = .3709
(Base x sh-wx) F_2	O	146	14	24	48	49	8	10	22	169	12	3	12	55	6	1	6	X^2=15.7995
	C	142	22	25	57	47	7	8	19	153	11	8	19	51	4	3	6	P = .3959
(Yel.-res. x sh-wx) F_2	O	235	35	53	84					268	17	16	29					X^2= 5.8041
	C	239	37	42	96					257	19	14	32					P = .5633
(Wh.-res. x sh-wx) F_2	O	74	9	12	21	21	2	3	6	90	10	5	9	27	4	2	5	X^2=14.8062
	C	73	11	13	29	24	4	4	10	79	6	4	10	26	2	1	3	P = .4658
BACKCROSSES																		
(Tassel x sh-wx) x sh-wx B. C.	O	121	30	33	131													X^2= 3.2633
	C	131	26	26	131													P = .3574
	D	—10	+4	+7	—0													
(Base x sh-wx) x sh-wx B. C.	O	189	29	27	192													X^2= 3.4964
	C	183	35	35	183													P = .3270
	D	+6	—6	—8	+9													
(Base x sh-wx) x sh-wx B. C.	O	43	4	14	38	47	9	5	53									X^2=10.2197
	C	44	9	9	44	44	9	9	44									P = .1776
	D	+1	—5	+5	—6	+3	0	—4	+9									
(Yel.-res. x sh-wx) x sh-wx B. C.	O	66	13	19	66													X^2= 5.3776
	C	69	13	13	69													P = .1491
	D	—3	0	+6	—3													
(Wh.-res. x sh-wx) x sh-wx B. C.	O	105	17	25	103	100	20	19	116									X^2= 3.1273
	C	106	20	20	106	106	20	20	106									P = .3750
	D	—1	—3	+5	—3	—6	0	—1	+10									

*O=observed ratio; C=calculated ratio; D=difference.

The data have been treated as a two-class frequency distribution, and the significance of the difference in smut reaction is determined by comparison of the probable error of the difference in percentage as obtained from the formula $.6745 \sqrt{\frac{p \cdot q}{n}}$, in which (n) is the total number of individuals and (p) and (q) are percentages corresponding to the ratios concerned.

None of the endosperm classes obtained from crosses with the West Virginia resistant strains differed significantly from their normal sibs in regard to smut reaction when the above test was applied. The range of values observed varied from 0.5 to 2.9 times the probable error, which is well within the limit of non-significance. On the other hand, both tassel and base West Virginia strains indicate that the endosperm classes tested show significant differences in smut susceptibility from the comparable normal plants of the same family.

TABLE 6—*Smut reaction of backcross plants obtained from planting the different endosperm classes of seed of a cross between certain selfed strains and a shrunken-waxy tester*

Description of parents	Endosperm condition of plants	Number of plants	Place of infection						Percent infection	Diff.
			Tassel	Neck	Leaf	Ear	Below ear	Base		P. E.
(Tassel x sh-wx) x sh-wx B. C.	Normal	38	7	0	1	1	1	0	26.3	
	Waxy	36	8	1	7	2	2	1	58.3	6.64
(Base x sh-wx) x sh-wx B. C.	Normal	42	14	1	0	1	0	0	38.1	
	Waxy	33	15	0	3	0	0	1	57.6	3.86
(Yel.-resist. x sh-wx) x sh-wx B. C.	Normal	84	13	0	0	1	0	0	16.7	
	Waxy	81	3	0	1	3	2	1	12.3	1.79
(White-resist. x sh-wx) x sh-wx B. C.	Normal	112	5	1	1	2	1	0	8.9	
	Waxy	183	11	1	2	1	2	1	9.8	0.50
(Tassel x sh-wx) x sh-wx B. C.	Normal	36	6	0	4	1	1	0	30 6	
	Shrunken	38	10	1	4	2	2	1	52.6	4.37
(Base x sh-wx) x sh-wx B. C.	Normal	46	15	1	0	1	0	0	36.9	
	Shrunken	29	14	0	3	0	0	1	62.1	5.25
(Yel.-resist. x sh-wx) x sh-wx B. C.	Normal	77	9	0	0	3	0	1	16.9	
	Shrunken	88	7	0	1	1	2	0	12.5	1.85
(White-resist. x sh-wx) x sh-wx B. C.	Normal	140	9	2	1	2	2	1	12.1	
	Shrunken	157	9	0	2	1	1	0	8.3	2.56
(Tassel x sh-wx) x sh-wx B. C.	Normal	26	5	0	0	1	0	0	23.1	
	Sh-Waxy	26	8	1	3	2	1	1	61.5	6.89
(Base x sh-wx) x sh-wx B. C.	Normal	37	12	1	0	1	0	0	37.8	
	Sh-Waxy	24	12	0	3	0	0	1	66.7	5.37
(Yel.-resist. x sh-wx) x sh-wx B. C.	Normal	51	9	0	0	1	0	0	19.6	
	Sh-Waxy	54	3	0	1	0	2	0	11.1	2.95
(White-resist. x sh-wx) x sh-wx B. C.	Normal	70	3	1	1	2	1	0	11.4	
	Sh-Waxy	115	7	0	2	1	1	0	9.6	0.97

It is interesting to note the variations in total amount of smut as shown by a study of the next-to-the-last column in Table 6. Tassel and base are heavily smutted with an average of 42 and 50 percent, respectively, while the total smut of comparable white and yellow-resistant strains shows only about one-fourth as much, with 10 and 15 percent, respectively. Although the base strain does not

seem to maintain its ability to transmit infection to the basal portion of the plants in these populations, it does demonstrate a somewhat greater susceptibility than does the tassel strain. White-resistant backcrosses show on the average about 5 percent less infection than the yellow-resistant backcrosses.

Linkage Group II

The genetic tester used to test Linkage Group II was known to be homozygous for AA CC *R-g R-g* prpr, but the results of certain crosses indicated that this tester was also homozygous for (S), a factor which caused the aleurone to be spotted when the endosperm was *rr R*. West Virginia tassel, base, and yellow-resistant strains were pollinated with this tester, and the crossed seed showed spotting, which would be expected if dominant R and S came in from the tester parent.

These crossed seeds were planted. The smut reaction of the F_1 plants during the 1930 season is presented in Table 7.

TABLE 7—*Smut reaction of the F_1 plants from a cross of certain selfed strains and a spotted golden tester*

Description of parents	No. of plants	Place of infection						Percent infection
		Tassel	Neck	Leaf	Ear	Below ear	Base	
(Tassel x S-g) F_1	101	19	1	2	3	5	4	33.7
(Base x S-g) F_1	21	0	2	0	2	1	1	28.6
(Yel.-resist. x S-g) F_1	40	0	1	0	0	0	0	2.5

TABLE 8—*Color and aleurone condition of backcross and F_2 ears obtained from crossing certain selfed strains and a spotted-golden tester*

Description of parents		Description of aleurone and endosperm						
		Purple		Red		Yellow	White	Total
		Full	Spotted	Full	Spotted			
(Tassel x S.-g) F_2	Observed	506	218	172	82	555	190	1723
	Calculated	511	216	170	72	565	188	X^2=1.6781 P = .8856
(Base x S.-g) F_2	Observed	162	62	59	27	190	52	552
	Calculated	164	69	55	23	181	60	X^2=3.2352 P = .6646
(Yel.-res. x S.-g) F_2	Observed	182	82	78	33	221	63	659
	Calculated	195	82	65	27	216	72	X^2=6.0407 P = .3027
Totals	Observed	850	362	309	142	966	305	X^2=5.8586
	Calculated	870	367	290	122	963	321	P = .3217
BACKCROSSES								
(Tassel x S.-g) x S.-g	B. C.	90	84	84	92	X^2=1.2257		P=.7496
(Base x S.-g) x S.-g	B. C.	67	62	66	65	X^2= .2154		P=.80+
(Yel.-res. x S.-g) x S.-g	B. C.	349	339	360	370	X^2=1.526		P=.6809
Total	Observed	506	485	510	527			
	Calculated	507	507	507	507	X^2=1.76332		P=.6264

These data indicate that the F_1 plants are intermediate in amount of smut infection. The F_1 crosses involving the resistant strain show considerably less smut infection than those of the tassel and base strains. Certain of these F_1 plants were backcrossed to

the spotted golden tester while others were self pollinated. Table 8 presents data relative to color and aleurone condition of the backcross and F_2 ears produced. The counts recorded in Table 8 represent totals from one or more ears for each cross.

Deviations of observed and calculated numbers were such as might occur by chance about once in three trials, P equalling 0.32 for the F_2 ears, while the differences observed in the backcross might occur by chance twice out of three trials. Calculations for the F_2 spotted and full-colored endosperm class are based upon a theoretical crossover value of 12½ percent between the R and S loci.

Plantings were made of the different color classes obtained from the backcross ears, and careful notes regarding reaction to smut were recorded for individual plants during the summer of 1931. These data are presented in Table 9.

TABLE 9—*Smut reaction of normal and golden plants obtained from backcross seeds of a cross between certain selfed strains and a spotted-golden tester*

Description of parents	Plant description	Number of plants	Place of infection						Percent infection	Diff.
			Tassel	Neck	Leaf	Ear	Below ear	Base		P. E.
(Tassel x S-g) x S-g B. C.	Normal	102	28	0	5	4	6	2	44.1	
	Golden	81	21	1	1	6	7	0	44.4	0.09
(Base x S-g) x S-g B. C.	Normal	60	16	1	1	1	5	1	41.7	
	Golden	45	6	3	3	2	5	1	44.4	0.67
(Yel.-res. x S-g) x S-g B. C.	Normal	57	12	0	3	1	1	0	29.8	
	Golden	51	8	0	1	3	1	0	25.5	1.04

TABLE 10—*Smut reaction of the backcross plants obtained from the full-color and spotted-aleurone seeds of a cross between certain selfed strains and a spotted-aleurone tester*

Description of parents	Aleurone condition of seed	Number of plants	Place of infection						Percent infection	Diff.
			Tassel	Neck	Leaf	Ear	Below ear	Base		P. E.
(Tassel x S-g) x S-g B. C.	Full color	96	24	1	1	8	4	0	39.6	
	Spotted	80	25	0	5	2	4	0	45.0	1.4
(Base x S-g) x S-g B. C.	Full color	51	8	3	3	2	6	1	45.1	
	Spotted	54	14	1	1	1	4	1	40.7	0.9
(Yel.-res. x S-g) x S-g B. C.	Full color	103	16	1	4	4	2	0	26.2	
	Spotted	110	23	3	6	1	1	1	31.8	1.9

It will be seen from the column headed "percent infection" that the amount of smut in the tassel and base strains is nearly double that for the yellow-resistant, but in no cross is there a significant difference between the smut infection of the normal and golden plants when measured by the probable error of the difference.

Table 10 shows no significant differences between the amount of smutting found in the full-color and spotted aleurone classes for the crosses reported. These data are in full agreement with those obtained from the golden and normal plants.

The data presented in Table 11 indicate a linkage between the factors for spotted aleurone and golden plant color. The observed crossover value was 21 percent, which agrees fairly well with the previously reported value of 18.2 percent.

TABLE 11—*Relation between color and condition of aleurone of backcross seeds and the normal and golden plants obtained from these seeds*

Color of seed	Purple		Red	
	Full color	Spotted	Full color	Spotted
Color of plants	142 golden 24 green	30 golden 163 green	130 golden 55 green	40 golden 123 green

Linkage Group III

Linkage Group III is represented by sweet endosperm and tunicate plants. Tassel, base, white-resistant, and yellow-resistant strains were crossed with genetic testers known to be recessive for sweet endosperm. The crossed seed showed no effect of the "su" gene. This is as would be expected, since the West Virginia strains were homozygous starchy. Seeds from the above crosses were planted and notes recorded during the summer of 1930. Certain of these F_1 plants were backcrossed to testers recessive for su, while other F_1 plants were self-pollinated. Plantings were made of the sweet grains obtained from the backcross ears in the spring of 1931, and comparisons were made with normal plants of comparable genotype. The results are recorded in Table 12.

TABLE 12—*Smut reaction of normal and sweet plants obtained from backcross seeds of a cross between certain selfed strains and a sweet tester*

Description of parents	Endosperm condition of seed	Number of plants	Place of infection						Percent infection	Diff.
			Tassel	Neck	Leaf	Ear	Below ear	Base		P. E.
(Tassel x su) x su B. C.	Normal	33	6	0	0	0	4	4	42.4	
	Sweet	10	3	0	0	0	0	0	30.0	1.37
(Base x su) x su B. C.	Normal	205	30	7	0	12	18	4	34.6	
	Sweet	80	2	1	0	3	3	3	15.0	7.28
(Yel.-res. x su) x su B. C.	Normal	77	1	1	1	1	3	1	10.4	
	Sweet	55	4	1	0	0	0	0	9.1	0.50
(White-res. x su) x su B. C.	Normal	159	13	3	6	5	7	0	21.4	
	Sweet	96	7	3	1	1	1	0	13.5	3.36

Plants grown from backcross seed involving yellow-resistant and sweet do not show a significant difference between the normal and sweet segregates in regard to smut reaction — a difference of only 0.5 times the probable error being observed. In the cross involving white-resistant and sweet the difference is 3.36 times the probable error, the plants from the sweet seed being the more resistant. This represents a probability of a little over 1 to 38 that the differences may be due to chance. The cross involving the tassel strain is not significant, but that with the base strain is undoubtedly so, with a difference of 7.3 times its probable error. The

tendency is for the sweet plants to show less smut than the normal plants of similar genotypes. These differences are not significant in two crosses, doubtfully significant in a third, and very probably so in a fourth cross.

There are a few data available regarding the tunicate factor, located on the same chromosome with sweet, that may be of value in analyzing the smut relation that exists here. Both white and yellow-resistant strains were crossed with tunicate, which is a dominant plant character. F_1 plants produced from this crossed seed were grown in 1930 and self-pollinated. Plants from this seed were grown in 1931 and field notes recorded regarding the reaction to smut. These data are shown in Table 13.

TABLE 13—*Smut reaction of tunicate and normal plants obtained from F_2 seeds in a cross between certain selfed strains and a tunicate tester*

Description of parents	Description of plants	Number of plants	Place of infection						Percent infection	Diff.
			Tassel	Neck	Leaf	Ear	Below ear	Base		P. E.
(White-resist. x Tu) F_2	Tu	55	8	0	0	0	0	0	14.5	
	tu	23	0	1	0	1	0	0	8.7	1.46
(Yel.-resist. x Tu) F_2	Tu	50	10	0	0	0	2	0	24.0	
	tu	19	1	0	0	1	1	0	15.8	1.45

TABLE 14—*Smut reaction and linkage obtained from the F_2 plants in a cross between yellow-resistant and a sweet-tunicate tester*

Description of parents	Endosperm of seed planted	Starchy				Sweet			
		Tunicate		Normal		Tunicate		Normal	
	Appearance and smut infection of F_2 plants	Smutted	Free	Smutted	Free	Smutted	Free	Smutted	Free
(Yel.-res. x Tu-su) F_2		12	38	3	16	8	12	..	2
	Observed	50		19		20		2	
	Calculated	47		21		21		2	

There is no indication from these data that the tunicate chromosome is associated with resistance, as one would be led to believe from the evidence from the crosses of sweet factor. The tendency seems to be for the tunicate plants to show greater susceptibility to smut, although this is not marked, being only 1.5 times the probable error. Only one cross is available which includes both tunicate and sweet. These factors came in together in the tester used and were crossed on West Virginia yellow-resistant strain.

The crossed seed was normal in appearance and, when planted, gave rise to F_1 plants that were tunicate in appearance. One of these plants on being selfed gave 356 starchy seeds and 106 sweet, as compared to a calculated ratio of 345 starchy to 115 sweet.

In the spring of 1931, 75 of these starch grains and 25 sweet grains were planted and produced plants as shown in Table 14, giving 69 starchy plants and 22 sweet. Notes were recorded on these

plants as indicated in the table, and the segregation into tunicate and normal was determined. The observed classes gave an exceptionally close fit ($X^2 = 0.4296$) to the calculated values when a crossover value of 28.6 percent is assumed between Tu and su loci. The smut reaction of the F_2 plants is such as to indicate no linkage relation with either the Tu or su genes.

Linkage Group IV

The genetic tester used for Linkage Group IV was known to be recessive for liguleless, a plant character. West Virginia tassel, base, yellow-resistant, and white-resistant strains were pollinated with this tester. The crossed seed was normal in appearance. This was grown in the field during the summer of 1930 and the notes included in Table 15 were recorded for the smut reaction of the F_1 plants for the respective crosses.

TABLE 15—*Smut reaction of the F_1 plants from the cross of certain selfed strains and a liguleless tester*

Description of parents	No. of plants	Place of infection						Percent infection
		Tassel	Neck	Leaf	Ear	Below ear	Base	
(Tassel x lg) F_1	103	4	0	0	0	24	15	41.7
(Base x lg) F_1	102	12	3	1	1	34	8	57.8
(Yel.-resist. x lg) F_1	105	0	0	0	0	0	1	1
(White-resist. x lg) F_1 ...	71	0	0	0	0	0	0	0

TABLE 16—*Smut reaction of normal and liguleless plants obtained from backcross seeds in a cross between certain selfed strains and a liguleless tester*

Description of parents	Description of plants	Number of plants	Place of infection						Percent infection	Diff.
			Tassel	Neck	Leaf	Ear	Below ear	Base		P. E.
(Tassel x lg) F_2	Lg	70	17	2	2	3	0	4	40.0	
	lg	16	3	1	0	0	0	0	25.0	2.05
(Tassel x lg) x lg B. C.	Lg	43	9	0	0	0	4	4	39.5	
	lg	62	6	0	1	0	11	4	35.5	0.98
(Base x lg) x lg B. C.	Lg	50	5	1	0	2	9	4	42.0	
	lg	49	2	3	1	0	15	3	42.0	1.49
(Yel.-resist. x lg) x lg B. C.	Lg	67	1	0	0	2	5	1	13.4	
	lg	94	2	0	0	3	30	8	45.7	11.51
(White-resist. x lg) x lg B. C.	Lg	58	5	1	0	0	3	0	15.5	
	lg	49	5	0	1	0	4	1	22.5	2.18

The F_1 plants from the tassel and base crosses show a high percentage of smut. This would suggest that the liguleless tester has contributed susceptible genes that are similar to those borne by the West Virginia susceptible parent strains. If this is the correct assumption, the factors for susceptibility contributed by the liguleless tester behave as recessives when they are associated with either of the West Virginia resistant strains.

Certain of the F_1 plants from each cross were backcrossed to the liguleless tester, and the seed thus obtained was planted in 1931. Table 16 presents data which show the comparison of normal and liguleless plants in regard to smut reaction.

Neither backcrosses involving tassel or base strains gave a significant difference in the amount of smut observed in the normal and liguleless segregates — the difference observed being 0.98 and 1.49 times the probable error for these strains. In crosses with white and yellow-resistant strains, however, differences of 2.2 and 11.5 times their probable errors were observed. This would suggest that there is a significant relation between the smutted plants in the normal and liguleless classes and that the liguleless character is associated with susceptibility. Just what this relation is, whether morphological or physiological, is undetermined at present. It is hoped to study this chromosome more completely by building up testers of known smut reaction in order to determine any linkage relations that may exist.

TABLE 17—*Smut reaction of yellow and non-yellow plants obtained from the backcross seed of certain selfed strains and a yellow-endosperm tester*

Description of parents	Description of endosperm of seed	Number of plants	Place of infection						Percent infection	Diff.
			Tassel	Neck	Leaf	Ear	Below ear	Base		P. E.
(Tassel x y) x y B. C.	Yellow	164	32	2	0	12	5	3	32.9	
	Non-yellow	70	13	3	0	5	5	0	37.1	1.08
(Base x y) x y B. C.	Yellow	114	15	8	1	4	8	3	34.2	
	Non-yellow	70	7	0	0	8	7	0	31.4	0.75
(Yel.-res. x y) x y B. C.	Yellow	77	3	0	1	2	0	1	9.1	
	Non-yellow	79	2	2	1	2	1	0	10.1	0.45
(White-res. x y) x y B. C.	Yellow	37	0	3	0	0	0	0		
	Non-yellow	28	0	0	0	0	0	0		

Linkage Group V

Data are brought together in Table 17 to represent the difference between yellow and non-yellow endosperm. All of the West Virginia strains except the white-resistant carried yellow endosperm. These data represent plants grown from backcross seed that was either yellow or non-yellow, as shown by examination of the seed prior to planting in the spring of 1931. It is apparent from the differences shown in the last column of this table that there is no difference in the yellow and non-yellow endosperm plants in regard to reaction to smut.

Linkage Group VI

The genetic tester used for Linkage Group VI was known to be recessive for brachytic and fine stripe. Both are plant characters, the former causing a marked shortening of the internodes and giving a characteristic telescoped appearance to the plant, while the latter causes the leaves to be striped. The latter character was not easily classified in the segregating material, but the brachytic character was very sharply defined.

West Virginia base, yellow, and white-resistant strains were pollinated with the brachytic fine-stripe pollen, and plants from the

TABLE 18—*Smut reaction of the F_1 plants from a cross of certain selfed strains and a brachytic fine-stripe tester*

Description of parents	No. of plants	Place of infection						Percent infection
		Tassel	Neck	Leaf	Ear	Below ear	Base	
(Tassel x br-f) F_1	99	7	0	1	17	21	1	47.5
(Base x br-f) F_1	104	6	1	0	3	20	14	42.3
(Yel.-res. x br-f) F_1	51	0	0	0	2	0	2	7.8
(White-res. x br-f) F_1	90	1	1	0	0	0	0	2.2

seed thus produced were grown during the 1930 season. Smut reaction of these F_1 plants is recorded in Table 18.

These data are somewhat similar to other F_1 data obtained during 1930. The resistant strains seem to demonstrate their resistance in these crosses; the white-resistant parent apparently is much more resistant than the yellow-resistant.

Certain of these F_1 plants were backcrossed with pollen from the brachytic fine stripe tester, while other F_1 plants were self-pollinated. These backcross seeds were planted in 1931, and the reaction of the base and two resistant families to smut infection during 1931 is recorded in Table 19.

The results from the data obtained from backcrosses in all three families indicate that there is more smut infection in the brachytic than in the normal plants within the same family. In the base strain this amounts to 2.4 times the probable error, while in the yellow and white-resistant strains the difference is 3.1 and 5 times the probable error, respectively.

TABLE 19—*Smut reaction of normal and brachytic plants obtained from backcross seed in a cross between certain selfed strains and a brachytic fine-stripe tester*

Description of parents	Description of plants	Number of plants	Place of infection						Percent infection	Diff.
			Tassel	Neck	Leaf	Ear	Below ear	Base		P. E.
(Base x br-f) x br-f B. C.	Br	95	4	0	2	1	27	7	43.2	
	br	117	6	0	3	36	10	5	51.3	2.36
(Yel.-res. x br-f) x br-f B. C.	Br	137	16	1	2	2	10	1	23.4	
	br	149	6	1	1	15	19	4	30.9	3.07
(Wh.-res. x br-f) x br-f B. C.	Br	42	2	0	0	1	1	1	11.9	
	br	59	6	0	0	9	2	0	28.8	5.0

These two latter cases are probably significant and since they are based upon data obtained from resistant West Virginia strains they indicate a relationship between smut susceptibility and the brachytic character.

Since the tester used carried both brachytic and fine stripe recessive characters it was possible to identify the crossover classes from the backcross populations. From a total backcross population of 1167 plants 529 were normal, 39 normal fine-stripe, 37 brachytic normal-leaf, and 562 were brachytic fine-stripe. This gives a calculated crossover value of 6.5 percent between the br and f loci. This is somewhat higher than the value of 5.4 percent reported by

previous workers *(7)*. Altogether 218 F_2 plants were grown that were observed to segregate as follows:

	Br F	Br f	br F	br f
Observed	170	6	4	38
Calculated	155	6	6	47

$X^2 = 3.8417$

The P value obtained is .282, which indicates a good fit to expected ratios. Although there were only 39 crossover plants that were normal fine-stripe and 37 brachytic non-striped, there is nearly twice as much smut in the latter as in the former group. That portion of the chromosome can be identified which originated with the West Virginia strains. This fact suggests that factors for smut susceptibility are more closely associated with the brachytic locus than with the locus for fine stripe. It is unfortunate that the numbers are limited and that all of the crossover plants could not have arisen from West Virginia resistant strains.

Linkage Group VII

The genetic tester used for Linkage Group VII was ramosa — a character which affects plant and ear; the tassel usually has but one main spike with a tendency for the secondary spikes to be greatly branched. The ear shoots at first appear normal but early show a branching tendency which causes the husks to rupture, leaving the bulk of the developing ear exposed.

West Virginia base, yellow, and white-resistant strains were crossed with pollen from the ramosa tester. This seed was planted in the spring of 1930 and some of the F_1 plants were smutted as shown in Table 20. These data indicate a rather heavy infection for West Virginia tassel and base strains but show marked resistance for the two resistant strains.

TABLE 20—*Smut reaction of the F_1 plants obtained from a cross between certain selfed strains and a Ramosa tester*

Description of parents	No. of plants	Place of infection						Percent infection
		Tassel	Neck	Leaf	Ear	Below ear	Base	
(Tassel x ra) F_1	47	1	0	0	6	11	2	42.6
(Base x ra) F_1	99	0	0	0	6	18	12	36.4
(Yel.-res. x ra) F_1	88	0	0	1	2	2	0	5.7
(White-res. x ra) F_1	78	0	0	0	1	1	0	2.6

Certain of these F_1 plants were backcrossed with pollen from the ramosa tester, and plants were grown from this seed during the 1931 season. Data showing the smut reaction of normal and ramosa plants coming from each backcross are presented in Table 21.

Practically all of the smut found on ramosa plants was observed on the ears. The percentage of smutted ramosa plants is nearly the same whether the plant comes from a base or a resistant strain. When the relation between the normal and ramosa plants is measured by the criterion used in previous crosses, this difference is found to be highly significant.

These data seem to indicate that gross morphology plays a very important role in the smut behavior of plants and that, in this instance at least, the morphology of the plant has overcome, to a great extent, any physiological resistance which might have been present.

TABLE 21—*Smut reaction of normal and ramosa plants obtained from the backcross seed in a cross between certain selfed strains and a ramosa tester*

Description of parents	Description of plants	Number of plants	Place of infection						Percent infection	P. E. Diff.
			Tassel	Neck	Leaf	Ear	Below ear	Base		
(Base x ra)	Ra	56	4	6	3	8	1	0	39.3	
x ra B. C.	ra	52	3	0	0	46	0	0	94.2	12.5
(Yel.-res. x ra)	Ra	55	6	0	0	3	1	0	18.2	
x ra B. C.	ra	47	0	0	0	43	1	0	93.6	21.5
(Wh.-res. x ra)	Ra	62	2	0	0	0	0	2	6.5	
x ra B. C.	ra	39	1	0	0	29	0	1	82.1	35.8

Linkage Group VIII

Plants representing Linkage Group VIII came from three sources. The smut reaction of the plants produced from seeds with purple and red aleurone previously reported in Tables 5, 6, 8, and 10 differ with respect to the "Pr" gene and can be used to represent this linkage group. No significant differences were observed in the smut reaction of the normal plants coming from purple and red aleurone seeds; therefore the data are not repeated in this section.

Brevis-like *(25)* plants were found as segregates in the F_2 and certain backcrosses with two of the genetic testers (although these testers were not known to carry the brevis factor at the time they were used as pollinators). The segregating plants give some information in regard to the smut reaction of this character. The tester used to represent Linkage Group VIII was virescent #2. West Virginia tassel, yellow, and white-resistant strains were pollinated by virescent #2 pollen. The crossed seed was grown during 1930 and the smut reaction of the F_1 plants is recorded in Table 22.

TABLE 22—*Smut reaction of the F_1 plants obtained from a cross between certain selfed strains and a virescent No. 2 tester*

Description of parents	No. of plants	Place of infection						Percent infection
		Tassel	Neck	Leaf	Ear	Below ear	Base	
(Tassel x V^2) F_1	49	6	1	0	0	3	0	20.4
(Yel.-res. x V^2) F_1	55	0	0	0	0	3	1	7.3
(Wh.-res. x V^2) F_1	105	1	1	0	0	0	0	1.9

The amount of smut obtained from the F_1 plants of the cross between West Virginia strains and the virescent #2 tester is somewhat less than that obtained for most F_1 plants. The West Virginia resistant strains seem to show about their usual amount of resistance. Certain of the F_1 plants grown in 1930 were back-

crossed with pollen from the virescent #2 tester, and the field notes taken of the plants grown from this backcross seed are recorded in Table 23.

It is of particular interest to note here that there is apparently a significant difference between the normal and virescent #2 plants in regard to amount of smut infection: the virescent #2 plants show less smut in each of the three families. This difference is 7.1 times its probable error in the cross with West Virginia tassel strain and 5 times its probable error when both resistant families are considered, but only 2 times the probable error with the white-resistant strain alone.

TABLE 23—*Smut reaction of normal and virescent plants obtained from backcross seed of a cross between certain selfed strains and a virescent No. 2 tester*

Description of parents	Description of plants	Number of plants	Place of infection						Percent infection	Diff.
			Tassel	Neck	Leaf	Ear	Below ear	Base		P. E.
(Tassel x V²) x V² B. C.	Normal	77	30	1	0	3	4	3	53.2	
	Virescent	24	2	1	0	1	0	0	16.7	7.1
(Yel.-res. x V²) x V² B. C.	Normal	80	1	1	0	3	2	0	8.7	
	Virescent	20	0	0	0	0	0	0	0.0	5.0
(Wh.-res. x V²) x V² B. C.	Normal	194	3	4	0	0	0	0	3.6	
	Virescent	104	1	0	0	1	0	0	1.9	1.9

TABLE 24—*Smut reaction of normal and brevis plants obtained from F_2 and backcross seeds of a cross between certain selfed strains and a brevis tester*

Description of parents	Description of plants	Number of plants	Place of infection						Percent infection	Diff.
			Tassel	Neck	Leaf	Ear	Below ear	Base		P. E.
(Tassel x bv) F_2	Normal	69	17	2	2	3	0	4	40.6	
	Brevis	22	2	0	0	1	0	4	33.3	1.1
(Base x bv) x bv B. C.	Normal	28	4	0	1	6	3	2	57.1	
	Brevis	15	4	1	0	7	0	0	80.0	3.3
(Yel.-res. x bv) x bv B. C.	Normal	133	10	9	1	12	4	4	30.1	
	Brevis	27	1	3	0	11	6	0	74.1	7.7

During the late summer of 1931 certain families were observed to be segregating for brevis-like plants. The factor for brevis apparently was carried in the heterozygous condition in both the liguleless and crinkly dwarf tester. The smut reactions of the brevis and normal plants which appeared in crosses with West Virginia tassel, base, and yellow-resistant strains are shown in Table 24.

Although the number of plants is not large, the difference in smut reaction of the normal and brevis plants clearly indicates the greater susceptibility of the brevis plants. It is particularly interesting to note that of the three types of plants that represent this linkage group, none shows similar smut reaction. Those plants that differ only by the "Pr" gene, that determines aleurone color, show no relation to smut, while the virescent #2 plants are resistant and the brevis plants show an equally striking smut susceptibility.

Linkage Group IX

The genetic tester used for Linkage Group IX was represented by crinkly, dwarf$_1$, and tassel seed #4. Recent evidence obtained by Brink *(2)*, Emerson, Hofmeyr *(15)*, and by McClintock *(27)* indicates that the d_1-pg_2 group and the A-ts^4 group are in reality all linked, and these are discussed as representing Linkage Group IX. The genetic tester used to represent this group was known to be segregating for crinkly, dwarf$_1$, and tassel seed #4. West Virginia tassel, base, yellow, and white-resistant strains were crossed with the Group IX tester, and the reaction of the F_1 plants obtained is presented in Table 25.

TABLE 25—*Smut reaction of the F_1 plants obtained from a cross between certain selfed strains and a crinkly-dwarf$_1$-tassel seed No. 4 tester*

Description of parents	No. of plants	Place of infection						Percent infection
		Tassel	Neck	Leaf	Ear	Below ear	Base	
(Tassel x cr-d_1-ts^4) F_1	51	16	0	0	2	9	0	52.9
(Base x cr-d_1-ts^4) F_1	65	3	0	0	2	8	5	27.7
(Yel.-res. x cr-d_1-ts^4) F_1 ..	91	3	3	0	5	2	0	14.3
(White-res. x cr-d_1-ts^4) F_1	29	0	1	0	0	0	0	3.4

Certain F_1 plants were backcrossed to the crinkly-dwarf$_1$-tassel seed #4 tester while others were self-pollinated. The smut reaction of these backcrosses and F_2 plants is given in Table 26.

TABLE 26—*Smut reaction of normal, crinkly, dwarf$_1$, and tassel seed No. 4 plants obtained from the F_2 and backcross seed of a cross between certain selfed strains and a crinkly-dwarf$_1$-tassel seed No. 4 tester*

Description of parents	Phenotype of B. C. and F_2 plants	Number of plants	Place of infection						Percent infection
			Tassel	Neck	Leaf	Ear	Below ear	Base	
Base x cr-d_1-ts^4 F_2	Cr D TS^4	47	4	3	0	4	7	2	42.6
	Cr D ts^4	26	24	0	0	1	0	1	100.0
	cr D TS^4	5	1	0	0	0	2	1	80.0
	cr D ts^4	6	6	0	0	0	0	0	100.0
	cr d Ts^4	9	0	0	1	2	0	0	33.3
	cr d ts^4	2	2	0	0	0	0	0	100.0
Base x cr-d_1-ts^4 B. C.	TS^4	79	39	2	1	2	8	4	70.9
	ts^4	28	27	0	0	0	0	0	96.5
	Cr TS^4	75	9	1	0	0	10	22	56.0
	Cr ts^4	6	5	0	0	0	1	0	100.0
	cr TS^4	10	1	0	0	1	3	3	80.0
	cr ts^4	15	13	0	0	0	0	0	86.7
Base x cr-d_1-ts^4 B. C.	Cr D TS^4	28	4	0	1	6	3	2	57.1
	Cr D ts^4	11	7	0	0	4	0	0	100.0
	cr d TS^4	30	4	2	0	10	3	0	63.3
	cr d ts^4	6	4	2	0	0	0	0	100.0
Yellow-resist. x cr-d_1-ts^4 B. C.	Cr D	102	10	9	0	11	3	3	35.3
	cr D	5	0	0	0	2	0	0	40.0
	Cr d	1	0	0	0	0	0	0	00.0
	cr d	71	1	3	1	13	4	1	32.4
White-resist. x cr-$d_1$ts^4 F_2	Cr D TS^4	59	11	0	0	0	0	1	20.3
	Cr D ts^4	10	9	0	0	0	0	0	90.0
	cr D TS^4	6	0	0	0	0	0	0	00.0
	cr D ts^4	1	0	0	0	0	0	0	00.0
	cr d TS^4	12	0	0	0	0	0	0	00.0
	cr d ts^4	17	6	0	0	0	0	0	35.3

The number of plants listed under the different phenotypes of the backcross and F_2 segregating families is not large. The nature of the tester used is indicated by the type of segregation shown in the column headed "phenotypes of backcross and F_2 plants." For example, each of the three backcross ears grown from the West Virginia base x crinkly-dwarf$_1$-tassel seed #4 tester shows a different kind of segregation. No attempt has been made to fit the numbers of observed plants to calculated ratios; it is felt that the discrepancies can be accounted for by the differential viability of the tassel seed #4 and dwarf$_1$ plants.

The amount of smut observed for the different segregating types is very high. This is to be expected in those types where West Virginia base strain was used as one of the parents. It is of particular interest to see that the tassel seed #4 plants gave practically 100 percent infection and that nearly all of this smut was in the tassel portion of the infected plants. Where the West Virginia resistant strains are used as parents the smut is still high, but materially less than with the base strain as a parent.

Summary of Linkage Groups

Table 27 is a summary which shows the place and percentage of smut infection for all plants grown in 1931. These plants in some cases represent normal and segregating types from crosses involving West Virginia strains other than those reported previously. The chief purpose for presenting the data in this form is to bring together individuals in order to show the tendency of smut reaction for the different linkage groups.

The data have been grouped without regard to West Virginia parentage. Plants represented by Linkage Groups IV, VI, VII, IX, and the brevis plants of Group VIII show a greater percentage of smut in the segregates than in the normal plants within the same family.

If the above inference is correct: i. e., if these testers are concerned in the transfer of smut-susceptible genes as seems to be indicated by a study of the backcross and F_2 progeny involving these testers, it should be possible to detect differences in the reaction of the F_1 plants when the different testers are crossed with West Virginia strains. Table 28 shows the average smut infection of the F_1 plants from crosses between Linkage Groups I, II, and VIII with certain West Virginia strains, as compared with the F_1 plants from Linkage Groups IV, VI, VII, and IX with the same West Virginia strains. It is apparent that there is more smut produced on the F_1 plants with certain testers than with others. The reasons for this smut reaction of F_1 plants and its true significance are not apparent at the present time. Such results might be expected if the West Virginia, tassel, and base strains carry the same factors for susceptibility as those borne by the linkage testers. These susceptible factors could very easily be common to the testers in question and

may or may not be a function of the particular characteristic of the tester. The fact that neither of the West Virginia resistant strains shows this smut relation in F_1 plants would suggest that they carry factors that behave as dominants to those contributed by the genetic tester.

TABLE 27—*Summary of all plants, showing normals vs. segregates, with places and percentage of smut indicated*

Group	Name	Number of plants	Place of infection						Percentage of smut infection
			Tassel	Neck	Leaf	Ear	Below ear	Base	
I	Normal	525	69	9	7	10	5	3	19.6
	Shrunken	496	68	3	11	7	10	3	20.6
	Normal	489	74	7	5	8	7	0	20.7
	Waxy	428	61	5	13	9	8	6	23.8
	Normal	347	55	7	3	7	3	0	21.6
	Shrunken-waxy	354	49	3	9	6	6	3	21.5
II	Normal	447	77	6	14	18	25	6	32.7
	Golden	313	63	8	8	16	16	3	36.4
	Full color	435	83	7	13	19	18	3	32.9
	Spotted	427	75	9	15	17	23	7	34.2
III	Normal	71	3	1	0	1	1	1	9.8
	Tunicate	185	29	0	0	1	4	0	18.4
	Normal	1129	93	29	17	34	65	24	23.2
	Sweet	512	27	7	6	7	14	5	12.9
IV	Normal	629	55	12	4	16	45	21	24.3
	Liguleless	443	31	5	3	8	89	28	37.0
V	Yellow	1229	139	19	23	35	69	26	25.3
	Non-yellow	910	116	22	18	33	37	19	26.9
	Purple	432	37	5	0	16	26	14	22.7
	Sunred	333	36	4	5	12	9	12	23.4
	Brown	97	9	1	0	3	5	1	19.6
	Green	122	12	0	3	2	6	3	21.3
VI	Normal	692	57	7	9	22	69	26	27.4
	Brachytic	639	36	3	6	130	76	11	41.0
VII	Normal	403	23	14	6	18	9	4	18.4
	Ramosa	352	7	0	0	273	5	2	81.5
VIII	Normal	499	62	9	2	8	11	11	20.6
	Virescent No. 2	192	5	2	0	2	1	0	5.2
	Normal	404	37	18	4	31	23	12	30.9
	Brevis	85	2	7	0	26	13	5	62.3
IX	Normal	536	37	48	2	47	36	15	34.5
	Dwarf,	287	10	8	2	66	25	2	39.4
	Normal	361	73	8	3	25	36	35	49.9
	Tassel seed No. 4	133	108	2	0	5	1	1	88.0

TABLE 28—*Smut reaction of F_1 plants from crosses between certain West Virginia strains and known genetic testers*

Strain	Percent smut of Linkage Groups	
	I - II - VIII	IV - VI - VII - IX
Tassel	24.0	45.7
Base	29.8	42.4
Yellow-resistant	3.5	6.9
White-resistant	0.9	1.9

Several cases have been presented where the data indicated that gross morphology of the plant was the determining cause of smut reaction. It is possible that the morphology of the plant plays an important role in those selfed strains where resistance and susceptibility can be demonstrated but where it has not been possible

to observe changes in form that will account for the reaction. The F_1 plants resulting from crosses with linkage testers are of particular interest in this connection, since they are all normal in appearance. It is therefore not so probable that gross morphology of the plant is playing such an important role in determining smut reaction.

The work of Immer *(17)* at Minnesota suggests a linkage with the "B" and "P" groups which corresponds with Groups IV and VI of this report, but he failed to obtain indication of linkage in "Bn" and "A" groups, which correspond to groups VII and IX of this report. Since Linkage Groups VII and IX were the ones showing the most distinct relationship between morphology and smut reaction, it would appear that choice of a linkage tester with respect to morphological characters is very important in such studies.

This emphasizes the importance of knowing something about the smut reaction of the linkage tester used. Work is now under way at the West Virginia Experiment Station looking toward the synthesis of linkage testers that will give definite smut reaction similar to the selfed lines reviewed earlier in this paper. When these linkage testers are obtained it is hoped that crucial tests for smut inheritance can be made.

DISCUSSION

Certain selfed strains of maize were grown under smut-epiphytotic conditions and careful notes were recorded on the smut reaction of individual plants within each selfed line. Certain lines of maize were obtained which showed sharp differences in regard to place and amount of smut infection. Crosses between these selfed lines showed clearly that reaction to smut is a strain peculiarity that can be transmitted from parent to offspring.

Segregation observed in the backcross and F_2 generations indicated that a complex condition exists and that many factors are concerned in inheritance.

Crosses between West Virginia selfed lines and certain linkage testers indicate that at least four testers show a linkage relation with smut susceptibility. The F_1 plants corroborate the conclusions in regard to the above susceptible groups and in a manner to minimize the peculiar morphology of the plant.

Gross morphology no doubt plays a very important role in the reaction of smut. The fourth linkage group is represented by the liguleless character, which produces a plant that does not have the leaf sheath tightly clasped about the main stalk. Most of the smut reported for these plants was found in the lower regions of the plant. This might follow if the smut spore were to fall on the leaf and be washed back of the leaf sheath, where conditions are favorable for germination and infection.

Linkage Group VI is represented by the brachytic factor, which causes a marked dwarfing or shortening of plant internodes. When the ear shoots appear the leaf sheaths are ruptured, and an excellent

focal point for infection of the inner meristematic tissue is presented. Most of the infected brachytic plants observed were found to be infected on the ear and below the ear.

Linkage Group VII is represented by "ramosa". The most pronounced feature is the excessive branching of the ear, which soon causes the protecting husks to rupture and expose the young spikelets of the developing ear. It was observed that over 95 percent of the "ramosa" plants were smutted in the ear. The "ramosa" plants obtained from the yellow and white-resistant West Virginia strains showed 93.6 and 82.1 percent infection, respectively, which would indicate, in this case at least, that the morphology of the plant had a greater influence on smut reaction than any resistance that came in from their respective West Virginia parents.

Linkage Group VIII was represented by the virescent #2 tester as well as certain brevis-like plants that were observed to segregate from other genetic testers.

The F_1 plants as well as the backcross and F_2 plants from the virescent #2 tester showed marked resistance to smut. These virescent #2 plants were observed to be late and weaker than their normal sibs. The fact that they were late might have let them escape smut infection; or it is possible that the stunted growth also brought about a physiological condition within the plant that was not favorable to smut infection.

"Brevis" is a recessive plant character that causes decided shortening of the internodes of the plant. The character resembles "brachytic" in this respect, but the shortening of the internodes is limited to a portion of the plant. The result generally produces a semi-dwarf condition with a characteristic bunching of the leaf blades. In most cases there is a marked twisting of the culm that accompanies the shortening of the internodes. This tendency for the culms to twist causes the leaf sheaths to split and expose the young tissue of the plant, usually in the vicinity of the ear shoot. This condition produces a favorable point of entrance for the smut spores and may be one reason why the "brevis" plants were found to show such high percentages of smut when compared to their normal sibs.

Linkage Group IX is represented by the crinkly-dwarf$_1$-tassel seed #4 tester. "Crinkly-dwarf$_1$" and (A-ts^4) were formerly considered as separate groups, but recent work by Brink, by Emerson, by Hofmeyr, and by McClintock indicates that the old groups IX and X are linked; therefore they are discussed together.

The genetic material used for a tester was segregating for crinkly, dwarf$_1$, and tassel seed #4. The latter character produces seed in the tassel and will not produce an ear shoot unless the tassel is removed. The F_1 plants were obtained by crossing the West Virginia strains on a crinkly-dwarf$_1$ tassel seed #4 plant. Backcrosses were made by using pollen from crinkly-dwarf plants which, in some of the cases reported, were also heterozygous for tassel

seed #4. These data are all presented in Table 26 and need not be discussed further here. The most interesting feature about the data is the behavior of the tassel seed #4 plants in regard to smut reaction. These plants approach 100 percent infection when the West Virginia base strain is used as one parent. Here again is an excellent place to show the effect of a favorable morphology upon the amount of smut infection produced. Tassel seed #4 normally produces a mass of silks and seed in the tassel. This mass is exposed soon after emergence and offers an excellent place for infection to occur. Although the amount of smut infection is high when the West Virginia resistant strains are used as the parents, there is a decided decrease in the amount of smut from that observed for the West Virginia base strain.

The data indicate that reaction to smut is probably conditioned by two sets of factors. One controls the physiological behavior of the plant; the other is concerned with its morphological characteristics.

The presence of factors governing physiological resistance is well illustrated in crosses involving the West Virginia yellow and white-resistant strains. These strains exert their influence on the smut reaction of progeny even where the morphology is such that the plants should smut heavily.

There are also cases where the gross morphology apparently obscures any physiological resistance that is present as seen in the cross with "ramosa".

The F_3 generation of the cross between yellow and white-resistant strains has given a population of highly-resistant plants which show considerable promise as foundation stock for further breeding work. The present indications are that a resistant strain with highly desirable agronomic characters can be obtained.

SUMMARY

Selfed lines of maize that show sharp differences in amount and place of smut infection have been isolated.

The F_1 plants from crosses between certain selfed lines of maize that differ in amount of smut infection show an amount of smut intermediate to that of the parent lines.

The tendency of the offspring to resemble the parent lines in regard to place of infection is less clearly defined than their reaction to amount of smut.

Direct and reciprocal crosses in general gave similar results.

Results of crosses between certain selfed lines and representatives of nine linkage groups indicate that at least Groups IV, VI, VII, and IX are associated with smut susceptibility. It is shown that each of the above groups was represented by plants where gross morphology might play an important role in the reaction of a plant to smut.

The F_3 progeny resulting from the intercrosses of the most resistant selfed lines indicate that it will be possible to isolate desirable agronomic types that are highly smut-resistant.

It is concluded that in so far as the host is concerned two sets of genetic factors seem to control the reaction of any particular strain to smut. One group of factors is concerned primarily in the control of physiological behavior and the second is concerned with the morphology of the plant. It is felt that by more complete testing of the linkage groups, certain genetic factors not readily identified with morphological differences may be found that will show linkage with factors controlling physiological conditions.

LITERATURE CITED

(1) Arthur, J. C., and Stuart, W.
1900. corn smut. Ind. Agr. Exp. Sta. Ann. Rep. 12:84-135.

(2) Brink, R. A., and Senn, P. H.
1931. heritable characters in maize xl. ragged, a dominant character, linked with A_1, TS_4, and D_1. Jour. Her. 22:155-161.

(3) Christensen, J. J., and Stakman, E. C.
1926. physiologic specialization and mutation in *Ustilago zeae*. Phytopath. 16:979-999.

(4) Coffman, F. A., Tisdale, W. H., and Brandon, J. F.
1926. observations on corn smut at akron, colorado. Jour. Amer. Soc. Agron. 18:403-410.

(5) Eddins, A. H.
1929. pathogenicity and cultural behavior of *Ustilago zeae* from different localities. Phytopath. 19:885-916.

(6) Emerson, R. A.
1912. the inheritance of certain abnormalities in maize. Amer. Breed Assoc. Report. 8:385-399.

(7) ————
1929. summary of linkage groups in maize. Mimeograph summary. Department of Plant Breeding, Cornell Univ.

(8) Garber, R. J., and Quisenberry, K. S.
1925. breeding corn for resistance to smut, *Ustilago zeae*. Jour. Amer. Soc. Agron. 17:132-140.

(9) ————, and Hoover, M. M.
1928. the relation of smut infection to yield in maize. Jour. Amer. Soc. Agron. 20:735-746.

(10) Griffiths, Marion A.
1928. smut susceptibility of naturally resistant corn when artificially inoculated. Jour. Agr. Res. 36:77-89.

(11) Hanna, W. F.
1929. studies in the physiology and cytology of *Ustilago zeae* and *Sorosporium reilianum*. Phytopath. 19:415-442.

(12) Hayes, H. K., Stakman, E. C., et al.
1924. reaction of selfed lines of maize to *Ustilago zeae*. Phytopath. 14:268-280.

(13) Heald, F. D.
1926. manual of plant diseases. McGraw Hill Book Co.

(14) Hitchcock, A. S., and Norton, J. B. S.
1896. corn smut. Kans. Agr. Exp. Sta. Bul. 62.

(15) Hofmeyer, J. B.
1930. male sterility in maize. Thesis, Plant Breeding Department, Cornell University.

(16) Immer, F. R., and Christensen, J. J.
1925. The reaction of selfed lines and crosses of maize to *Ustilago zeae*. Phytopath. 15:699-707.
(17) ————
1927. The inheritance of reaction to *Ustilago zeae* in maize. Minnesota Agr. Exp. Sta. Tech. Bul. 51.
(18) ————, and Christensen, J. J.
1928. Influence of environmental factors on the seasonal prevalence of corn smut. Phytopath. 18:589-596.
(19) ————, ————
1928. Determination of losses due to smut infection in selfed lines of corn. Phytopath. 18:599-602.
(20) ————, ————
1931. Further studies on reaction of corn to smut and effect of smut on yield. Phytopath. 21:661-674.
(21) Jones, D. F.
1918. Segregation of susceptibility to parasitism (smut) in maize. Amer. Jour. Bot. 5:295-300.
(22) Jorgensen, L. R.
1929. Effect of smut infection on the yield of selfed lines and F_1 crosses in maize. Jour. Am. Soc. Agron. 21:1109-1112.
(23) Kyle, C. H.
1929. Relation of husk covering to smut of corn ears. U. S. D. A. Tech. Bul. 120.
(24) ————
1930. Relation between the vigor of the corn plant and its susceptibility to smut, *Ustilago zeae*. Jour. Agr. Res. 41:221-231.
(25) Li, H. W.
1931. Heritable characters in maize. Brevis. Jour. of Heredity 22:14-16.
(26) Macmillan, H. G.
1918. An epidemic of corn smut following hail. Phytopath. 8:584-585.
(27) McClintock, B., and Hill, H. E.
1931. The cytological identification of the chromosome associated with the R-G linkage group in Zea mays. Genetics 16:175-190.
(28) Piemeisel, F. J.
1917. Factors affecting the parasitism of *Ustilago zeae*. Phytopath. 7:294-307.
(29) Plant Disease Reporter Supplement.
1932. United States Department of Agriculture, Bureau of Plant Industry.
(30) Potter, A. A., and Melchers, L. E.
1925. Study of the life history and ecological relations of the smut of maize. Jour. Agr. Res. 30:161-175.
(31) Ranker, E. R.
1930. The nature of smut resistance in certain selfed lines of corn as indicated by filtration studies. Jour. Agr. Res. 41:613-619.
(32) Selby, A. D., and Hickman, J. F.
1897. Corn smut. Ohio Agr. Exp. Sta. Bul. 78.
(33) Stakman, E. C., and Christensen, J. J.
1926. Physiologic specialization of *Ustilago zeae* and *Puccinia sorghi* and their relation to corn improvement. (Abstr.) Phytopath. 16:84.
(34) ————, ————
1927. Heterothallism in *Ustilago zeae*. Phytopath. 17:827-834.
(35) ————, ————, et al.
1929. Mutation and hybridization in *Ustilago zeae*. Minnesota Agr. Exp. Sta. Tech. Bul. 65.
(36) Tisdale, W. H., and Johnston, C. O.
1926. A study of smut resistance in corn seedlings grown in the greenhouse. Jour. Agr. Res. 32:649-668.

Bulletin 254 December, 1932

Report of the West Virginia Agricultural Experiment Station for the Biennium Ending June 30, 1932

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

TABLE OF CONTENTS

	PAGE
DIRECTOR'S STATEMENT	3
Research and Progress in Agriculture	3
Adapting Research to Changing Conditions	12
Problems Awaiting Investigation	13
Continuity in Research Necessary for Progress	15
Other Services of the Experiment Station	15
Location of Research Projects	16
REPORTS OF CURRENT RESEARCH	17
Agronomy and Genetics	17
Animal Husbandry	25
Chemistry (Agricultural)	29
Dairy Husbandry	30
Entomology	34
Farm Economics	38
Home Economics	43
Horticulture	44
Plant Pathology	50
Poultry Husbandry	54
STAFF LIST	56
Staff Changes	57
LIST OF CURRENT PROJECTS	57
PUBLICATIONS OF THE BIENNIUM	59
Bulletins and Circulars of the Experiment Station	59
Technical Bulletins Published Jointly with the U. S. Department of Agriculture	59
Scientific Papers of the Experiment Station	60

Report of the West Virginia Agricultural Experiment Station for the Period from July 1, 1930, to June 30, 1932

DIRECTOR'S STATEMENT

WITH THIS REPORT the Experiment Station completes 45 years of service to West Virginia agriculture. Established in 1888, it is the oldest of the several agencies maintained by the state and federal government to provide assistance to the farmer. Its period of service coincides with the period of greatest progress in the development of modern agriculture, in which the station has played an important part.

For a number of years the station was almost the sole influence in stimulating interest in the use of improved farming practices as well as in establishing the basis for such practices through experimentation and research. More recently other agencies have been created to deal with special aspects of the better-farming movement: the Cooperative Extensive Service, the State Department of Agriculture, and the Vocational Division of the State Department of Education. Since their establishment the station has been free to devote its principal activities to the purpose for which it was created — the advancement of agriculture through research — and noteworthy progress has resulted.

RESEARCH AND PROGRESS IN AGRICULTURE

It is the purpose of this report not to treat of the history of the station in any detail but rather to show the relation of its contributions to the modernization of agriculture in West Virginia. The prime purpose is to promote a better understanding by the general public of the character and value of research and experimentation in the field of agriculture. There is abundant evidence that the work is returning to the public many times its cost. Before considering the work of the current biennium, which appears in the reports of the departments, it will be worth while to review the major contributions of other years.

Improved Methods of Soil Maintenance

The soils of West Virginia are unusually diverse as to origin, type, and productivity. The maintenance of fertility and the economical use of land are a major concern of the orchardist, the vegetable gardener, the livestock producer, the dairyman, the general farmer,

the forester, and in fact of every one engaged in any phase of agricultural production. In the construction of roads, in the creation of parks and preserves, in the location of schools, and in other services it is the major concern of the state that the productive capacity of the soil and its ability to support a rural population be clearly and accurately determined. The importance of knowing the correct basis for the use of fertilizers and lime is shown in the fact that our annual purchase of commercial fertilizers approximates 50 thousand tons, and some 15 thousand tons of lime is used each year as a soil amendment. The annual outlay exceeds one and one-half million dollars.

The station has contributed to the knowledge of soil maintenance by:

Classifying and mapping the soils of the state in cooperation with the Bureau of Chemistry and Soils of the United States Department of Agriculture and the State Geological Survey. Many different soil types are found in the state, all differing in their level of productivity, topography, or other features. The soil type may determine the kind of crop which can be grown or the kind of farming practices that should be employed. Some soils undoubtedly are too steep for agricultural purposes and some are suited primarily to grazing, whereas others can be used to grow cultivated crops.

Determining the fertilizer and lime requirements for many of the soil types and establishing the fact that most of the soils in West Virginia are deficient in phorphorus and lime. On the other hand potash fertilizers have not given marked increases in yields except with potatoes and in some cases with alfalfa. In apple orchards some form of nitrogen fertilization is necessary, and information concerning the most economical form has been made available.

Determining the amount of organic matter in West Virginia soils and the effect of various cover crops in maintaining the organic matter and productiveness of soils. In a study of 485 soils from different sections of the state it has been found that the organic matter varied from 0.68% to 15.13%. The average content was 2.84%. These results show that some of the soils are very deficient in organic matter. The most dependable cover crop for general purposes has been found to be a mixture of rye and winter vetch. The importance of studies of the value of organic matter in maintaining the water-holding capacity of soils, particularly of orchard soils, was well shown during the drought of 1930, and further studies along this line are in progress.

Investigations in apple orchard culture have shown that permanent sods of alfalfa, of sweet clover, or of some of the grasses maintain growth and yield as well as or even better than clean cultivation with a winter cover crop, provided additional amounts of nitrogen are added. Permanent cover crops build up organic matter of the soil and help prevent erosion.

Investigating the nature of soil acidity in its relation to plant growth. It has been found that aluminum in very low concentrations may be toxic to plants. Soils from various locations in the state were studied and it was found that in general the more acid ones contained the more soluble aluminum. The use of lime on acid soils takes aluminum out of solution and therefore removes it as a source of plant injury.

Studies of pasture fertilization have shown the value of phosphorus and lime in increasing productivity and in encouraging the growth of better types of grasses and legumes. The prevailing practice of plowing and reseeding permanent pastures has been shown to have little value unless accompanied by liming and fertilization. The pasture crop is the most valuable one in West Virginia and exact knowledge of its maintenance and improvement is of great practical significance.

Better Crop Plants and Methods of Culture

Almost without exception the varieties of crops in use today are of recent origin, having been developed through selection and hybridization. High yield, quality, disease resistance, soil and climatic adaptation, and other factors have been the basis for improvement. The agriculture of the state has been greatly enriched through the introduction of new crops and the use of better varieties of old crops. The station has conducted extensive varietal tests of field crops, forage crops, fruit crops, and vegetables, and has propagated and distributed the varieties having greatest value. It has under way a continuous program of plant breeding that has created a better variety of soybeans and gives promise of a smut-resistant oat, a smut-resistant corn, a disease-resistant watermelon, and a more palatable and better-adapted sweet clover. Some of the more important contributions of the station may be mentioned here.

The introduction and dissemination of the soybean has made available to the West Virginia farmer a valuable legume. Breeding activity with this crop has resulted in the development of Pekwa, a new variety, highly productive of fine-stemmed hay and one that retains its leaves better than any other variety grown in the state. This characteristic is particularly important in haymaking.

The introduction and dissemination of Gopher oats, one of the highest-yielding and stiffest-strawed varieties known.

Woodburn White dent corn was introduced into Mason county several years ago and found to outyield other varieties commonly grown in that section. From this focal point the new variety has been distributed to many farmers who are well pleased with its performance.

An investigation to determine the frequency of cutting alfalfa has shown that three cuttings in one season give best results. Fewer cuttings reduce yields and more cuttings injure the stand. In a decidedly abnormal season such as that of 1930 it may not be desirable to remove more than two crops.

The standard varieties of red raspberries do not grow successfully in West Virginia because of winter injury. The introduction and testing of Latham, which does not have this weakness, has made it possible for red raspberries to be grown successfully in this state.

One of the chief causes for failure of medium red clover has been found to be the use of unadapted seed. Clover seed produced in Ohio, Michigan, Maryland, Virginia, and Tennessee has given satisfactory results, particularly the strains resistant to anthracnose.

Investigations of the station have helped to standardize the varieties of potatoes grown in the state. At the lower altitudes Cobblers primarily are grown and at the higher altitudes Rurals give best results. Significant contributions have also been made in regard to cultural practices and the practicability of using home-grown seed.

The need of mixed plantings of varieties in orchards to insure pollination has been brought to the attention of fruit growers through the work of the station. The best varieties for such use are being determined and the information is being applied by fruit growers in their recent plantings.

The West Virginia station has been a leader in the study and development of systems of pruning for fruit trees. The moderate system that it advocates has come into general use with increased profits to growers. These studies show clearly that the established practice of severe pruning dwarfs the trees, delays fruiting, and lowers production.

Significant progress in the adoption of better varieties of vegetable crops and in the production of new crops has resulted from experimental work in the Ohio valley. The Break O'Day and Pritchard varieties of tomato and the Bender muskmelon may be mentioned among new varieties. Crops new to the section include eggplant, peppers, Chinese cabbage, and green-sprouting broccoli.

More Efficient Control of Insect Pests and Plant Diseases

The development of commercial agriculture in West Virginia, as elsewhere, has intensified the problems of parasites, both insects and plant diseases, and has made their successful control one of the most important factors in profitable production. It is freely stated by fruit growers that the development of a commercial fruit industry in West Virginia would have been impossible except for the services of the Experiment Station and allied agencies in solving the problems of disease and insect control. Nor could orcharding be maintained except for such services, since new problems are continually arising. Like conditions also apply to many of our field, garden, and forest crops. The recent virtual extermination of the chestnut tree illustrates the destructive capacity of uncontrolled diseases, and the present abundance of the Mexican bean beetle serves as a reminder to the home gardener as well as the commercial grower of the ever-present need of new remedies for new pests.

The service of the station in these particular fields has extended over a period of more than twenty years, and his been marked by particularly outstanding contributions to fundamental knowledge as well as effective relief measures for problems of an emergency character.

Among the many contributions the following are particularly noteworthy.

The effective control of apple rust was made possible by establishing definite proof of the benefits obtained from the eradication of the red cedar. The loss in one county in a single season from this disease is estimated to have exceeded $75,000. The further prevention of serious loss in sections where the eradication of cedars is impracticable has been promoted, through a comprehensive study of the susceptibility to rust of 66 commercial varieties of apple. Some of the varieties are practically immune and may be used in sections where cedars abound without serious loss.

Established potato growing on a firm basis by solving problems of disease control through spraying and use of disease-free seed. Exhaustive series of experiments show that spraying doubles yields.

Established effective measures for protection of orchards from insects and diseases by thorough and continued study of a large number of proprietary and new spray materials and spray schedules. Demonstrated greater efficiency of liquid spraying as compared with dusting.

A new method of preparing Bordeaux mixture that saves time, reduces costs, and yields a more uniform and better spray material.

New insecticides for the Mexican bean beetle and other garden insects.

Life history studies and control measures for many serious insect pests, notably the bean beetle, pistol-case bearer, stalk borer, corn ear-worm, cabbage and radish maggots, codling moth, apple aphids, and San Jose scale.

Established the relationship between weather conditions, particularly temperature, and insect growth and activity, making possible predictions of abundance of insects and facilitating the timing of control measures. These principles have been widely applied elsewhere.

Established the principle of control for the Hessian fly by observing the "fly-free" date for sowing wheat. This practice has been followed for many years throughout the winter wheat belt and has been of great practical value.

Discovery of the cause of apple "measles", a hitherto obscure disease, with promise of effective control measures in the near future.

Discovery of a serious canker disease of black walnut with rapid progress in studies of cause and control.

Fundamental studies of the natural variation in plant parasites of special importance in the problem of breeding disease-resistant crop plants.

Contributed much original and timely knowledge concerning insect pests of forest trees.

Better Methods of Breeding, Feeding, and Managing Farm Animals

Because of the adaptation of West Virginia to livestock, dairy, and poultry production the station from the time of its establishment has devoted especial attention to problems in these fields and has conducted many studies leading to the improvement of breeding, feeding, and management practices. Most of our exact knowledge of animal nutrition is the product of the work of the experiment stations and these studies have also contributed important facts to the understanding of human nutrition. The findings of station research have been carried to the farmer by means of bulletins, demonstrations, and educational campaigns and have resulted in noteworthy improvement in quality with substantial economies in production costs. Strong market preferences for West Virginia lambs, beef cattle, and eggs have been created as a result of a high level of quality and careful systems of grading. Brief mention of some phases of the station work follows.

One of the largest breeding experiments with dairy cattle, conducted at the Reymann Memorial Farms, has advanced the use of proven sires and demonstrated their possibilities.

Greater values in the use of purebred sires in the production of steers and market lambs have been clearly established, and exact data concerning their use have been recorded.

Calves sired by purebred bulls and marketed as two-year-old steers have greater value than those sired by grade or nondescript bulls. Lambs sired by purebred Shropshire and Hampshire rams are superior in weight to those sired by purebred Southdown and Cheviot rams, but the latter grade higher and dress a higher percentage. Recent studies of the use of Corriedale rams on grade Hampshire ewes show marked gains in length of staple and weight of fleeces of the yearling ewes as compared with their dams. The weight, grade, and dressing percentage of the wether lambs equalled that of lambs sired by Shropshire and Hampshire rams.

Feeding experiments with beef cattle have been directed chiefly to the problems of finishing steers for market in the belief that West Virginia farmers will profit more through the production of finished animals rather than stocker and feeder steers. Considerable data as to the value of grain supplements fed to cattle on pasture for varying periods and as to the economy of feeding in the drylot and during the wintering period have been made available to farmers and are furnishing the basis for a better and more profitable live-

stock industry. The greater potential values in the finishing and marketing of animals at an earlier age than is currently practiced in the state has also been shown.

Feeding experiments with pigs have included a variety of protein supplements to the corn ration. In particular a comparison of the values of buckwheat middlings, linseed meal, and cottonseed meal has been made. While good results were obtained with all, the most rapid gains with lowest food consumption were obtained with buckwheat middlings.

Feeding experiments with dairy cattle have included trials with different legume hays, mangels, and sunflowers as substitutes for corn silage, and extensive studies of mineral requirements. The production of soybeans in the state has been greatly stimulated as a result of the evidence that they are equal in value to alfalfa hay. Many dollars in feeding costs have been saved through the evidence that minerals need not be added to the ration for growing dairy heifers provided they receive pasture in the summer and plenty of roughage in the winter. A study of simplified, home-grown rations now in progress promises further feeding economies for the dairyman.

The value of animal protein in the poultry ration was established in early work at the station and further studies of a variety of ingredients have helped to establish the constituents of standard formulas and the basis for the feeding of home products.

Much new information has been developed concerning the relation of nutritive constituents and the rate of feeding to egg production and hatchability. Hatchability is increased by liberal feeding and by the use of sprouted oats and is not lowered by a high rate of production preceding the hatching season.

Of especial value in the improvement of breeding practices for high egg production have been the very extensive and fundamental studies of the factors affecting the weight of eggs and the relation of egg weight and volume of production to the weight and age of fowls.

Comprehensive studies of cycles in egg production show that the first egg of the cycle is laid early in the forenoon and the remainder later and later on succeeding days until late afternoon is reached. The bird then ceases to lay for a day or two and then repeats the cycle as before. The more prolific layers usually have the longest cycles.

More Efficient Control of Animal Diseases

The early work of the station in this important field has consisted chiefly of the interpretation of research conducted elsewhere and the application of the findings to West Virginia conditions. It is only in recent years that original research has been included in the station program and as yet the work is limited in scope because

of inadequate funds. Nevertheless substantial progress in the solution of some of the more important problems of animal pathology has been achieved. A laboratory for the diagnosis of diseases of animals is maintained in cooperation with the State Department of Agriculture. This renders an important service to the livestock, dairy, and poultry producers of the state and is closely coordinated with and supplemental to the research service.

Recent and current research deals chiefly with two projects: the problem of infectious abortion, which is responsible for great economic losses through loss of calves, sterility, reduction in milk, and predisposition to disease in the offspring, and the problem of the control of stomach and lung worms, which is a major concern of the stockman and sheep producer.

Methods of herd management for the control of infectious abortion in dairy and beef cattle have been developed which point the way to a satisfactory solution of this important problem. The method involves the gradual elimination of diseased animals and the prevention of further spread of disease by means of complete or part-time isolation of reactors. The complete segregation of infected animals in the station herd at Wardensville has resulted in elimination of the disease. Part-time isolation, isolation during the period of calving, is rapidly achieving similar results at Morgantown. Of 73 animals in the station herd in June 1930, 20 reacted to the agglutination test. In June 1931 the number had been reduced to 12 in a total of 77 animals, and in June 1932 only 3 animals in the herd of 77 were reactors. Part-time isolation will doubtless prove the most practical method in West Virginia since most of our farms do not have facilities for complete isolation.

The need for more exact information concerning dosage in the treatment of stomach worms and for effective measures for the control of lung worms has been apparent through the excessive losses sustained and the repeated requests for advice from stockmen and farmers. The work to date has involved a considerable number of sheep at the station farm and has included a variety of materials and concentrations. Rapid progress has been made and the findings have been applied to privately-owned flocks with complete success.

Better Methods of Farm Management

The readjustment of production to meet changing market requirements and to promote the best economy in the use of capital and labor has been fostered through a series of farm management studies conducted solely by the station or in cooperation with the Bureau of Agricultural Economics of the U. S. Department of Agriculture and other agencies. In the transition from the general, self-sustaining agriculture of the earlier days to the more specialized, commercial agriculture of today, the need for accurate appraisal of the sources of profit has been especially evident and the contributions of the station have been of great value in supplying correct and time-

ly information on a variety of questions. These studies have included:

A market-garden survey of the Ohio and Kanawha valleys with the delimitation of areas suitable for the development of trucking, and recommendations for the improvement of current practices.

General studies of the organization of the farm business in typical counties with particular emphasis on the amount of labor and other costs involved in the production of the leading crops.

Studies of the management and organization of typical, specialized farms showing the relation of profits to size of farm and other factors.

Special studies of the business of orcharding, poultry farming, and wool production, together with a particular study of the construction, management, and economic efficiency of stationary spraying systems for apple orchards.

A comprehensive farm management and land-use study of Nicholas and Webster counties, from which an economic program for agriculture and forestry has been developed.

Better Marketing of Farm Products

Closely allied to research in farm management are the studies of marketing organizations and marketing which have received attention in recent years.

Studies of the production of staple farm commodities in four major consuming areas of the state together with consumption data for the principal markets, Charleston, Clarksburg, Beckley, and Wheeling, have disclosed opportunities for the expansion of production along certain lines that should be advantageous to both city and country.

The marketing of apples, including market outlets, marketing costs, and methods has been the subject of a recent comprehensive study made in the eastern section of the state in cooperation with the federal Bureau of Agricultural Economics. Many facts concerning this most important aspect of fruit growing have been made available to the growers.

Studies of costs, methods, and practices in the marketing of livestock have recently been completed. They include records of sales through various county livestock shipping associations as well as a large number of private sales. They offer definite suggestions for economies in marketing and improvement in the business transactions of the cooperatives.

Further studies of the business of cooperative marketing associations, including all active agencies in West Virginia, have been completed in cooperation with the Federal Farm Board and have supplied the necessary groundwork for the future development of cooperative marketing of a regional as well as state-wide character.

ADAPTING RESEARCH TO CHANGING CONDITIONS

During the biennium an unusual amount of attention was given to revising projects and recasting the research program to meet emergency problems in the agriculture of the state and to make adjustments to conform with reduced funds.

Each study received rigid scrutiny as to its value, timeliness, and productivity with the result that many were brought to a conclusion or completely revised. The scope of this recasting is seen by comparing the status of projects as of July 1928 with that of July 1932. Of a total of 91 projects at the beginning of the period 53 have been completed and 11 have been revised. Only 27 projects have been continued through the period and are now active. Half of these cover miscellaneous work or variety tests and rotation studies which are modified from time to time but are continuous as to the main objectives. The others are of such character that more than four years are required for their completion.

The completed projects have been replaced in part by 34 new projects, of which 18 have been adopted within the biennium. These together with the 11 revisions and the 27 continued studies make up the total of 72 projects that are now in operation.

The curtailment of work made necessary by the reduced budget has been effected with as little loss as possible. There has been no lowering of standards or tendency to reach hasty, ill-founded conclusions.

Among the new projects especial mention should be made of the farm management and land-use study of the Huntington area, comprising parts of the counties of Wayne, Cabell, Putnam, Lincoln, and Mason. The intensive study of large numbers of typical farms of this area is planned to reveal the types of farming best adapted to the area and the factors that are necessary for profitable farming. The productivity of the various soils, the quality and management of livestock, systems of cropping, market outlets, costs and incomes, and the human factor are all given consideration. The study is unique in that it enlists the cooperation of practically all departments of the Experiment Station and thus brings to a focus the knowledge and experience of the entire staff. The results will supply an effective basis for future planning in the area for land utilization, population movements, schools, roads, markets, and the like, and will be applicable in part to other areas of the state. The close cooperation of the Extension Division through the services of specialists and county agents gives assurance that the findings will receive greatest possible application.

Other recent studies have as their objectices:

The improvement of poultry management in the Parkersburg area.

The control of round worms in pigs through correct feeding.

Methods of herd management for the production of slaughter and feeder calves.

The use of green manures for maintaining soil fertility in vegetable crop rotations.

The use of simplified rations for dairy cattle with especial emphasis on the feeding of home-grown products.

The control of stomach and lung worms in sheep and cattle.

The value of deep tillage in the production of field, truck, and orchard crops.

The cause and control of the canker disease of black walnut.

Effective organization and operation of apple orchards.

PROBLEMS AWAITING INVESTIGATION

The current research program of the Experiment Station naturally does not include nearly all the problems that press for solution. It is necessary that a choice be made of the more urgent problems and those that the station is best equipped to solve, and that others be postponed until work in progress is completed or new personnel or facilities are made available. No exhaustive listing of problems awaiting investigation will be attempted but a few examples will serve to illustrate their character and scope.

One of the broad, major problems and the final goal of much of the research in progress lies in the proper utilization of the land resources of the state. A considerable amount of data contributing to the problem has been recorded, but these must be amplified with additional information and brought together from new viewpoints before any satisfactory attempt can be made to classify land according to future profitable use. The ground-work for a land-use program has been laid with the soil survey, which is now complete except for a single county. Information concerning productivity of soil types, farm incomes, and other economic data also exists for separate localities, notably for Nicholas and Webster counties.

A study of the Huntington area, now in progress, affords a further important contribution. With a return to normal conditions the state should undertake to finance a state-wide study of types of land utilization, so that more definite programs of public and private ownership and of agricultural, timber, and recreational uses can be formulated. The Experiment Station is devoting as large a part of its appropriations as possible to this important work and will continue to do so, but unfortunately the amounts available are such that a good many years will be required for completion. Obviously it is desirable that more rapid progress be made. To have greatest

value such a study should be completed within a short period. The costs of such work are not excessive. In New York they have averaged one cent per acre and in West Virginia, because of the uniformity of some of the large mountain areas, it is thought that even lower costs would suffice.

Closely allied to the problems of land use is the problem of soil erosion. Because of the topography of the state, erosion is particularly important in West Virginia not alone because of soil loss but also because of flood damage, which is a natural result when hillsides are denuded of forests or other vegetation. Serious losses of soil may take place even on relatively level land. Cropping plans and cultural practices should be so designed as to minimize the permanent loss of soil. The station has long recognized the importance of this need but because of a lack of funds and equipment has given little active attention to it.

The need for more exact information concerning soil-moisture relationships has been intensified by the droughts of recent years, especially that of 1930. The value of measures tending to minimize losses to farmers and fruit growers can readily be appreciated when we consider the losses of 1930, which were variously estimated to be in the neighborhood of thirty millions of dollars for West Virginia alone. While it is known in a general way that such factors as depth of soil, its organic content, character of subsoil, tolerance of varieties, and kinds of crops are of importance in determining the degree of injury in years of drought, much additional information of more specific character should be sought. There are also possibilities of using irrigation during critical periods especially with high-cost crops such as fruits and vegetables, and the economy of such practices should be investigated.

Within the period of this report a number of requests have been received for advice concerning the dying of forest and ornamental trees. Preliminary study has been made of several cases that should be investigated more fully. Except for the black-walnut canker, now being studied, and the chestnut blight but little attention has been given in West Virginia to the diseases of forest trees.

Among recent spray materials much interest has been displayed by fruit growers in the tar oils, which appear to offer promise of certain economies. Our own work has demonstrated that some of these preparations will kill apple aphids in the egg stage and that they offer possibilities for the control of the pistol-case bearer during the dormant season. As yet there are no standards to govern the use of these materials since the tar oils themselves are variable according to source of origin, and a thorough study of the properties of limited fractions seems essential to further progress. The solution of this problem would not only benefit the fruit growers but conceivably would further the coal industry of the state through utilization of by-products.

CONTINUITY IN RESEARCH NECESSARY FOR PROGRESS

Continuity is an important factor in the successful prosecution of research. Only rarely are agricultural projects completed within a single season. More often a period of two or more years is required and if the study deals with the testing of varieties of crops, or fertilizer applications, or food rations, or cultural practices, the period for completion is usually several years. Ten or more years are often needed to arrive at a definite goal in the development of a new crop variety through breeding. Hybridization, selection, and testing are time-consuming but essential processes. In the testing of varieties or materials the seasonal factor is an important one. Single-season results are seldom reliable guides to long-time behavior because of seasonal variations. The crop variety that is outstanding in a normal year may lodge in a wet season or fall short in a dry season. The farmer is concerned with performance over a long period and if research is to answer his requirements it must establish the facts in conformity with the seasonal variations that he encounters.

The investment in agricultural research is therefore of necessity a long-term investment. The security of the investment and the guarantee of satisfactory results are insured in large measure by the degree of continuity that is maintained. Enforced interruption or discontinuance of a study prior to completion may involve the loss of all that has gone before with waste of time, labor, and money. Because of these facts it is in the interest of economy to provide funds for research that will guarantee continuity during periods of depression as well as in times of prosperity.

The human factor is the all-important factor in research. Laboratories, equipment, land, and livestock cannot advance knowledge except as they are utilized by the trained worker. The guarantee of success for an experiment station lies, therefore, in the maintenance of a competent staff. Although salaries are not the sole factor in the building of a research staff they are quite necessary to obtain and hold competent workers, and the salary item should be the last to suffer from declining revenues and the first to be restored with increasing incomes.

OTHER SERVICES OF THE EXPERIMENT STATION

Although its principal function is the conduct of research the Experiment Station is called upon for a variety of other services for which it is particularly qualified because of special facilities and trained personnel. All such services are rendered free to citizens of the state.

The station cooperates with the State Department of Agriculture in maintaining the following laboratory services: the testing of purity and germination in seeds, the diagnosis of diseases of poultry and farm animals, the testing of fertilizers and animal feeds, and the determination of arsenic in spray residues on apples.

Further laboratory services conducted solely by the station include: miscellaneous chemical analyses, the testing of soil samples to determine lime requirements, the testing of limes to determine their value in agricultural use, and the scoring of blackberry jam prepared by farm women for sale under the Mountain State Brand.

Other services include:

The supervision of the testing of dairy cows for the Advanced Register.

The identification of plants, varieties of fruits, and farm crops.

The identification of injurious insects and of plant diseases.

The determination of effective dates for spray-service recommendations based on studies of insect and disease development.

The supplying of technical information on a wide range of subjects in response to specific inquiries.

Advice on organizing and managing the farm unit.

Information on farm lease contracts.

Plans for construction of farm buildings.

Aid to individual farmers in the improvement of small-grain crops through selection.

The station also cooperates with various agencies such as the College of Agriculture, the Extension Division, and the farm organizations of the state in assisting with special schools, educational tours, livestock improvement campaigns, and in the conduct of public meetings.

LOCATION OF RESEARCH PROJECTS

Agricultural research in West Virginia is centered in the seat of the Experiment Station at Morgantown and in the three outlying branch stations: the University Experiment Farm at Kearneysville, Jefferson county; Lakin Experiment Farm, Lakin, Mason county; and Reymann Memorial Farms, Wardensville, Hardy county. Yet the program of investigation and experimentation is not confined to these centers. It reaches out to all sections of the state, so that the conditions under which crops are grown or marketed may be studied at first hand. The appended list of counties tells how this program is divided according to the general lines of investigation followed.

*Animal Husbandry**: Greenbrier, Hardy, Monongalia, Pocahontas.

Crops and Soils: Grant, Hardy, Jefferson, Mason, Monongalia, Preston, Randolph.

Fruits and Vegetables: Berkeley, Hampshire, Jefferson, Mason, Monongalia, Morgan, Preston.

Insect Pests: Berkeley, Hampshire, Jefferson, Monongalia.

Plant Diseases: Berkeley, Hancock, Hardy, Jefferson, Mason, Monongalia, Morgan, Ohio, Putnam.

Farm Economics: Berkeley, Brooke, Cabell, Hampshire, Jackson, Jefferson, Lincoln, Marshall, Mason, Mineral, Monongalia, Morgan, Ohio, Putnam, Tyler, Wayne, Wetzel, Wirt, Wood.

*Includes Dairy Husbandry and Poultry Husbandry.

REPORTS OF CURRENT RESEARCH

The reports which follow concern the status and results of research work in the several departments of the Experiment Station for the biennium 1930-32.

AGRONOMY AND GENETICS

The agronomic projects have been planned with a view to helping solve the problems peculiar to West Virginia that pertain to field crops and soils. There are relatively few places in the state where the production and sale of field crops is the main agricultural enterprise. The principal farm income is more likely to be derived from the sale of livestock or livestock products, or from some horticultural crop. The experimental work in agronomy is therefore supplementary to and coordinated with the experimental work which deals more directly with the chief income-producing activities on West Virginia farms.

The orchardists are confronted with the problem of soil management and cover cropping. Studies are being carried on to determine what cover crops are most effective in supplying organic matter and hence increasing the water-holding capacity of the soil. Investigations with sweet clover include a breeding project in which an attempt is being made to produce a new strain particularly adapted to West Virginia orchards. Various cultural practices with respect to height and time of cutting sweet clover are being compared with a view to determining their relative value.

One of the important problems of the livestock farmer is the production of leguminous hay. Extensive investigations are being carried on with alfalfa on several soil types to determine the fertilizer and lime requirements. Soybean breeding has resulted in the development of a new variety named Pekwa, which is particularly well adapted for hay purposes. Additional leguminous crops are being investigated with the object of determining their value for conditions in the state.

Cost accounts show that dairy products can be most economically produced when pasture is available. In cooperation with the federal Department of Agriculture and the Dairy Husbandry department of this station, extensive pasture investigations are being carried on at the Reymann Memorial Farms and at several other places in the state. Some work is also being done with annual pasture crops. It is hoped that the results from these investigations will help the West Virginia dairyman in the problem of pasture management so as to enable him materially to reduce the cost of producing dairy products.

In addition to the activities indicated above there are a number of agronomic projects which have for their aim breeding for disease resistance. Under this category the following may be mentioned: corn resistant to smut, oats resistant to smut, tobacco resistant to

rootrot, and watermelons resistant to wilt. Several new smut-resistant strains of oats which have been produced by hybridization appear promising in the variety trials.

Practically every West Virginia farmer is confronted with problems pertaining to liming and fertilization. Approximately 700 field plats at the Lakin Experiment Farm are being used to study the fertilizer needs of the commonly-grown field crops, including potatoes. Laboratory and greenhouse studies on soil reaction have yielded some interesting results which may have an important bearing on the question of liming practice.

A service maintained by the experiment station of direct value to individual farmers is the testing of soil samples for lime requirement and in some cases for available phosphorus. On the basis of these tests advice is given as to lime and fertilizer treatments for certain crops. Another service of direct value to West Virginia farmers is the analysis of limestone for its neutralizing value when applied to the soil. During the past biennium 831 samples of soil have been examined for lime requirement and 550 samples of limestone analyzed for calcium carbonate equivalent.

In cooperation with the state department of agriculture a laboratory is being maintained for the purpose of testing seeds for germination and purity. This service helps to establish a high standard for seeds planted by West Virginia farmers.

Below are brief statements concerning the agronomic projects under way with particular emphasis on progress that has been made since the last biennial report was issued.

Pasture Improvement

In 1930 a comprehensive pasture investigation was begun at the Reymann Memorial Farms and at certain other locations in the state in cooperation with the U. S. Department of Agriculture. The principal experiment at Wardensville is being carried out on a 44-acre tract with approximately 40 Ayrshire cows. Here an attempt is being made to evaluate various combinations of fertilizers in terms of pounds of milk and pasture days. Inasmuch as grazing was just begun during the season of 1932 it is not yet possible to draw even tentative conclusions from this phase of the work.

Supplementary to the main experiment there was established a series of small plats on each of the following soil types: Dekalb and Westmoreland silt loams near Morgantown, Upshur clay loam near Aurora, Huntington silt loam near Moorefield, Dekalb shale loam near Petersburg, and Monongahela fine sandy loam near Wardensville. In these experiments differences between fertilizer treatments are being measured by clipping and weighing the grass at intervals of from two to five weeks and also by noting any changes in the character of the vegetation. It has been found that pastures on different soil types give different response to the same fertilizer treatment (See Table 1). In general a complete fertilizer has stimulated

the growth of cultivated grasses and clovers and hence reduced the stand of weeds.

TABLE 1—*Yield of grass per acre from different soil types*

Plot No.	Treatment	Yield in pounds per acre (dry matter)			
		Morgantown		Aurora	Moorefield
		Dekalb soil	Westmoreland soil†	Upshur clay loam	Huntington silt loam
..	Check	894	1942	660	1780
10	L	1038	....	812	1704
1	P	1104	2187	1064	1903
2	P-L	1254	....	994	2013
4	P-K	1191	2191	1022	1968
5	P-K-L	1771	....	967	1998
6	N-P-K	1727	2543	1336	2516
7	N-P-K-L	2243	....	1588	2458
11	1/2N-P-K-L ...	1924	2602*	1312	2151
12	2N-P-K-L	2472	....	1930	3144

*No lime applied.
†One of the highest-yielding cuttings is not available; therefore these figures represent probably 80% of the actual yield.

Annual Pastures

In the investigations being conducted with various legumes and grasses for the purpose of determining their relative value as annual pasture crops, biennial sweet clover has proved to be one of the most desirable. It usually furnishes plenty of grazing during that part of the season when bluegrass is most likely to be short.

Liming Pays

In the rotation experiment located on Wheeling fine sandy loam near Lakin, in which all the commonly-grown field crops are included, distinct increases in yield due to lime have been obtained with all crops except potatoes and cowpeas. Over the seven-year period the value of the increased yields due to liming is several times the cost of the lime. Liming experiments carried on elsewhere in the state in general corroborate the results obtained at Lakin.

Acid Soils May Contain Sufficient Soluble Aluminum to be Harmful

It was found in culture solution studies that soluble aluminum is decidedly injurious to various crops in concentrations as low as one part per million. In view of these results it seemed desirable to determine the concentration of soluble aluminum found in some of the representative acid soils of the state. In all about sixty soils were studied. Most soils below pH 5.0 were found to contain some soluble aluminum and one soil with pH value of 4.2 contained 27 parts per million of soluble aluminum. The greater the acidity of the soil and the higher the salt concentration, the more aluminum was found present in solution. These and other results obtained show that one reason why liming is beneficial to the growth of plants is that it takes the aluminum out of solution and renders it non-injurious to plants.

Excessive Liming May be Temporarily Injurious to Crops

In greenhouse studies with alfalfa and corn it has been found that the use of excessively large amounts of lime may result in a decided injury to the crop planted immediately after liming. This has been found to be due to the fact that the excess lime renders the phosphorus in the soil less available to the plant. Crops grown one year after liming showed little or no injury. While injury from excessive liming is not as likely to occur under field conditions, it is believed best, where large amounts (four tons or more per acre) of lime are to be added, to lime in the fall or at two different times during the rotation.

Wheat Yields Following Soybean vs. Cowpea Stubble

In a comparison between two three-year rotations at Lakin that are identical except that in the one soybeans are cut for hay and the stubble turned down and in the other cowpeas are treated similarly, the succeeding wheat crop has shown a difference of 4 bushels between the average yields over a seven-year period in favor of the crop following the cowpea stubble.

Wheat Responds to Nitrogen Fertilization

At the Lakin Experiment Farm the use of nitrogen fertilizer in the form of nitrate of soda has resulted in marked increases in the yield of wheat. The use of 130 pounds per acre of nitrate of soda increased the yields over 12 bushels per acre, whereas the use of twice that amount has resulted in yields more than double those where no nitrogen was applied. Detailed results are given in Table 2.

TABLE 2—*Effect of nitrogen on wheat yields in 1931 at Lakin Experiment Farm*

Treatment* in triplicated plats	Average yield (Bu.)
P - K	17.3
1/2N - P - K	24.6
N - P - K	29.7
2N - P - K	36.4
N - 2P - 2K	29.7
2N - 2P - 2K	38.1
4N - 2P - 2K	44.8

*N = 20 pounds nitrogen or 130 pounds nitrate of soda.
P = 60 pounds P_2O_5 or 300 pounds 20% superphosphate.
K = 20 pounds K_2O or 40 pounds muriate of potash.
N-P-K is equivalent of 500 pounds per acre of 4-12-4 fertilizer.
Rotation — Corn, wheat, and clover.

Corn also responded well to nitrogen fertilization. On the other hand the yields of both wheat and corn were not significantly increased on this Wheeling fine sandy loam soil from the use of phosphorus or potash fertilizers.

Some Nitrogen Available in Acid Soils

The value of lime in increasing the rate at which nitrogen becomes available for plants has long been recognized. Recent studies show that nitrates are produced in some of the most acid soils in the state. The pH of some of them was found to be less than 4.0 and the soluble aluminum content very high. The amount of nitrates produced in these soils is related to the supply of available calcium, which is the principal base found in limestone.

Three Cuttings Best for Alfalfa

In the frequency-of-cutting experiment with alfalfa it has been found that three cuttings give best results. The plats cut twice yielded somewhat less hay and hay of poorer quality. The plats cut four times showed greatly-reduced stands of alfalfa and a corresponding increase in weeds after the second year.

Phosphate Fertilization Important for Alfalfa

In both the greenhouse and field tests alfalfa has shown a marked response to phosphatic fertilization on practically all soil types. On the other hand no marked response to potash has been obtained.

Alfalfa May Grow on Slightly-Acid Soils

Studies in both greenhouse and field have been carried on to determine how much lime is required by West Virginia soils for the satisfactory growth of alfalfa. It was found that where the soil is well fertilized, good growth of alfalfa was obtained even though the soil is slightly acid — pH 6.0 to 6.5. In one experiment where lime was thoroughly mixed with the surface eight inches of soil the yields obtained from the use of 2¼ tons of hydrated lime (pH of 5.85) were only 11 percent lower than where 6 tons had been applied (pH 7.10). Where the lime was mixed with the surface 3 inches of soil the plats limed to pH 7.1 were found to give 42 percent greater yields than those limed to pH 5.85. The average amounts of ground limestone required for all the soils studied to bring them to pH 6.5 was 4 tons. To bring these same soils to pH 7.0 or neutrality required 6½ tons.

A Strain of Oats Resistant to Smut

During the biennium covered by this report the early maturing varieties of oats have continued to outyield the mid-season and late varieties. One of the early varieties introduced by the station is becoming widely grown in the state under the name of Gopher. Several years ago Gopher was crossed with Black Mesdag, a variety resistant to smut but otherwise undesirable. During the last two years certain smut-resistant white-seeded descendants from this cross have been included in the variety trials with gratifying re-

sults. The yields of some of the new strains compare favorably with Gopher and a few of them have less awn development.

New Variety Experiments with Wheat and Barley

Winter wheat and winter barley are grown extensively in the Eastern Panhandle. After the establishment of the branch experimental farm near Kearneysville it was deemed advisable to locate some variety experiments at that place. Accordingly variety trials with winter barley and winter wheat were established in cooperation with the federal Department of Agriculture. The variety trials at Morgantown and Lakin, as indicated in a previous report, continue to show Fulhio, Reliable 80, and Trumbull to be among the highest-yielding varieties of winter wheat for those locations. (Bul. 244.)

Inheritance of Reaction to Corn Smut

It has been shown by a study of the progeny resulting from crosses between resistant and susceptible corn that reaction to smut is definitely inherited. Not only is smut susceptibility transmitted from parent to offspring but, what is more striking, place of infection on the plant seems also to be a heritable character. During the past two years considerable information has been collected concerning the manner of inheritance of resistance and susceptibility to this important disease. It is hoped that this information will facilitate the production of high-yielding varieties of corn adapted to West Virginia that are resistant to smut.

Producing a Yellow-Seeded Woodburn White Dent

One of the highest-yielding white-seeded varieties of corn grown in the Point Pleasant area is Woodburn White Dent, which was introduced by the Experiment Station several years ago. The main objection to this variety is that it has white seed. A cross has been made between it and a strain of corn resistant to smut isolated from the variety Reid's Yellow Dent by self-pollination. The plants resulting from this crossed seed were again crossed with Woodburn White Dent. The ears so produced bore approximately 50 percent white and 50 percent yellow seed. Plants from the yellow seeds were again back-pollinated to Woodburn White Dent. It is expected to continue the process for a period of six or seven years with the aim of finally producing a variety of corn similar to Woodburn White Dent except in seed color.

Progress in Breeding Tobacco Resistant to Root Rot

In addition to the tobacco strains descendant from the crosses — Kelley x resistant Burley, and Pepper x resistant Burley mentioned in the previous biennial report (Bul. 244) — plant selections from the Pepper and Kelley varieties have been grown in soil known to be infested with the organism producing root rot. Some of these selections appear promising both from the standpoint of desirable type and resistance to root rot.

Breeding Watermelons Resistant to Wilt

A few years ago a Russian strain of watermelons resistant to wilt but not edible was crossed with Early Fordhook and with Grey Monarch. The two latter varieties are susceptible to wilt but of good edible quality. Second generation descendants from these crosses grown during the present year show a wide range of susceptibility to wilt and of edible quality. The object of this project, which is in cooperation with the department of Plant Pathology, is to produce a variety of watermelon that possesses resistance to wilt and high quality of fruit.

Pekwa, a New Variety of Soybean

The descendants of a single plant selection made from the Peking variety over ten years ago have proved valuable enough to justify giving them a variety name. The name chosen is Pekwa — "Pek" as the first syllable of the parent variety, and "wa" for "West Virginia". This new variety in addition to high yield possesses fine stems and retains its leaves unusually well during hay making.

Bundles of Pekwa (left) and Wilson (right) soybeans after flailing. Note superior leaf-retention on part of Pekwa

Concrete Soil Bins Used to Study Fertilizer Response

It is often difficult to find an area of land sufficiently uniform to be used for fertilizer studies. To overcome this difficulty soil bins having an area of 1/1000 of an acre each have been constructed on the Agronomy farm. The various layers of soil were well mixed

before being placed in the bins. The first crop of wheat and of soybeans showed that variation in yields due to natural variation had been largely overcome. Therefore these bins seem to offer a satisfactory method of studying fertilizer response. They are used at present in a study of availability of phosphate fertilizers.

Corn Sap May be Used to Determine Available Phosphate in Soil

The need for an accurate method for determining the availability of soil phosphates has led to the study of the phosphate content of corn sap as related to phosphate response. Recent studies in the greenhouse under controlled conditions indicate that there is a positive relationship between the phosphate present in the sap of corn and the yield. The tests are being continued in the field. Such variables as stand, weeds, moisture, and availability of other nutrients have been found to influence the amount of phosphate present in the plant.

New Fertilizers Prove Valuable

A new method of adding the nitrogen to mixed fertilizers, known as "ammoniation," has raised the question as to the availability of the phosphorus present in the new fertilizers. Since this method of manufacture has become widely used during the last few years, studies were undertaken in cooperation with the U. S. Department of Agriculture to determine the availability of the phosphorus. It was found that the tri-calcium phosphate formed as a result of ammoniation was as available to crops on slightly acid soils as is the phosphorus in superphosphate. As a result of these and other tests the official method for determining the phosphorus availability of fertilizers has been tentatively changed. Further studies are being made regarding this problem with soils of different degrees of acidity.

Application of Fertilizer in the Hill Better than Broadcast for Corn

In cooperation with the Joint Committee on Fertilizer Application of the American Society of Agronomy, studies have been made to determine the best method of applying fertilizer to corn. It was found that hill fertilization if properly done was much better than broadcast applications. One hundred and twenty-five pounds of fertilizer per acre applied in the hill was more effective in increasing yields than 500 pounds of the same fertilizer applied broadcast. The best method of applying fertilizer in the hill was found to be in two parallel bands two and one-half inches apart on either side of the seed and three-fourths inch above the seed level. Other methods of applying fertilizer in the hill were also effective, but all methods of hill fertilization in which the fertilizer was in contact with or too close to the seed were found to injure the stand and reduce the yields.

Frequency and Height of Cutting Sweet Clover

The question of height and frequency of cutting sweet clover is of particular interest to the orchardist. An investigation was begun recently to determine the effect of cutting sweet clover at different heights and at different stages of maturity. This work has not been in progress long enough to justify drawing conclusions at this time.

ANIMAL HUSBANDRY

The research program of the department of Animal Husbandry is designed to answer some of the more important problems confronting the farmers interested in beef cattle, sheep, and hogs. It is recognized that there are three essential things to be considered which make for economic production of meat animals: namely, health, breeding, and feeding.

Studies are now being made in connection with parasites of sheep and hogs. Rams of various breeds of sheep are being tested from the standpoint of market lamb production and from the standpoint of building up desirable ewe flocks when mated to native ewes. Cattle of various ages are being fed grain in conjunction with pasture to determine the amount of grain and the time it should be fed during the grazing season. Cow herds are being maintained under different systems of feeding and management to determine the most economical way to produce and sell calves. The majority of projects in progress with beef cattle and sheep of necessity center around the economic utilization of pasture — the most important farm crop in the state.

In addition to parasite work, studies are being made of various protein supplements in growing and finishing hogs. Studies are also conducted as to the accuracy of feeding experimental hogs in groups as against individual feeding.

Grain Supplement on Grass Pays for Itself

An investigation of beef production and quality as affected by grade of steer and by feeding grain supplement on grass was carried on for three years jointly by the Experiment Station and the Bureau of Animal Industry of the U. S. Department of Agriculture on typical bluegrass pasture land in southeastern West Virginia. Results obtained from the feeding of 40 steers of good and medium grade show that the gains and finish of three-year-old steers on good pasture can be increased sufficiently by the feeding of a grain supplement to more than offset the additional expense. Good and medium steers handled similarly during the winter feeding period and through the summer grazing period following may be expected to make similar total gains, the report states. The relative returns of each grade will therefore depend primarily upon the margins obtained.

In palatability tests it was found that the meat of the lots fed a

supplement on grass was of slightly greater tenderness. (U. S. D. A. Tech. Bul. 217.)

Finishing Calves for the Market

There is a place in West Virginia for the production of more good beef calves. Adjoining states offer a good market for our surplus feeder calves and it is not so speculative a phase of beef production as is the finishing of heavy steers.

A typical lot of steer calves used in the experiment

In a six-year experiment with good, grade, native Hereford and Aberdeen-Angus steer calves it was found that calves fed and marketed as baby beeves proved to have a greater potential value than calves fed and marketed either as 2-year-old or 3-year-old steers, and calves fed and marketed as 2-year-old steers had a greater potential value than calves fed and marketed as three-year-old steers. A short grain-feeding period for 2-year-old steers is less expensive and produces a more valuable slaughter animal than carrying them another year and marketing them as grass-fat three-year-old steers. Besides, the two-year-old steers so fed are more desirable for slaughter and for the market.

Grass alone, it was found, will not produce sufficient finish on two-year-old steers for slaughter. (Bul. 251.)

Herd Management for the Production and Slaughter of Feeder Calves

Does it pay to graze beef cows on land suitable for both tillage and pasture, or should beef herds be grazed only on strictly pasture land?

Sixty head of high-grade and purebred Hereford cows were divided into two equal lots late in 1931. One lot was wintered on the home farm of the Tuckwiller brothers, Greenbrier county, on a ration of corn silage, wheat straw, and cottonseed meal. The other lot was kept on mountain pasture nearby on a ration of mixed hay. In spring, 1932, cows and calves were turned on their respective pastures. A purebred Hereford bull was turned with each lot for a period of 2½ months.

Additional objects of the 5-year experiment are to study the cost of maintaining herds under the two systems; determining the necessary replacements of breeding animals as well as the percentage of calf crop raised; obtaining data concerning the net profit or loss per cow; and comparing grain rations fed to nursing calves on pasture that are to be finished for slaughter.

Finishing Two-Year-Old Steers on Grass and Grain

To determine the most economical period of feeding grain and at the same time to utilize pasture for the full grazing season, 30 yearling steers were wintered in 1930 on a daily ration composed of 20 pounds corn silage, 3 pounds mixed hay, 3 pounds oat straw, and 1½ pounds cottonseed meal. The average gain in weight per steer was from 652.5 pounds to 713 pounds, an average winter gain of 61.5 pounds. On April 17, 1931, the steers were turned on grass after separating into 3 equal lots of 10 each.

Lot I was started on 5 pounds grain (6 pounds cracked corn and 1 pound cottonseed meal) after the first 56 days on grass; Lot II, 7½ pounds of the same grain mixture after the first 84 days on grass; and Lot III, no grain on grass.

On September 4, or at the end of 140 days' grazing, all lots were fed a full grain ration for 56 days. Lots I and II were fed in bunks and remained on pasture while Lot III was removed from the pasture and fed in drylot.

These steers were sold on the Pittsburgh market at the end of the 56-day full-feed period and while they actually sold at different prices, the dressing percentages and carcass grades did not justify the spread in prices paid by the purchaser. The dressing percentages and the carcass grades indicated that all lots should have sold at approximately the same price. Net returns were in favor of Lot III.

This study is being repeated with 30 head of yearling steers.

Corriedale Topcross Increases Wool Yield

A study was begun in 1930 with 120 grade Hampshire ewes concerning the effect of a top-cross of Corriedale rams on the resulting crop of wool and mutton. The female progeny in turn were mated in the fall of 1932 to Corriedale rams and this procedure will continue for three or more generations. The wether lambs are sent to the laboratories of the Bureau of Animal Industry, U. S. Department of Agriculture, at Beltsville, Maryland, for the study of slaughter and carcass grades and weights as well as of quantity, quality, and palatability of meat.

Analysis of the data to date shows that the yearling ewes sired by Corriedale rams sheared approximately 80% heavier fleeces in the grease than their dams had as yearlings. These dams had sheared an average of 4 pounds, while their daughters averaged 7.23

pounds of wool. Likewise a decided increase in length of staple was noted in the case of the daughters, whose fleeces averaged 3.92 inches in length as compared to 3.16 inches for their dams. The daughters also averaged about 16 pounds or 23% heavier than their dams at the same age. The difference in weight is considered due largely to growth rather than fatness or condition. These yearling daughters are to be mated to Corriedale rams in the fall of 1932.

Control of Stomach and Lung Worms in Sheep

Stockmen and farmers in increasing numbers are requesting information concerning relief measures for stomach and lung worms. These diseases have not been fully investigated in either cattle, sheep, or swine, and remedial measures can be advised only empirically. As a calf and lamb-producing state West Virginia is in need of accurate information leading to the lessening of this important source of loss of farm livestock.

The department in 1929 undertook a detailed study of different drugs in their effect on several hundred lambs which were quartered in a specially constructed parasite barn with which was connected a securely fenced lot. Systematic treatment of sheep has been accomplished with the use of nicotine sulphate; nicotine sulphate and copper sulphate mixture; copper sulphate 1%; copper sulphate 1½%; colloidal iodine; tetrachlorethylene; and a mixture of equal parts of santonin, calomel, and aloin, for the removal of stomach and intestinal parasites.

A privately-owned farm flock of sheep, used in this experiment and numbering 23 ewes and their 29 lambs, was treated satisfactorily with copper sulphate.

A 1½% solution of this drug has given the highest percentage of efficiency in the control of stomach worms and other gastro-intestinal parasites.

Protein Supplements for Finishing Swine in Drylot

Four lots of 10 fall pigs each were fed from January to June 1932 on equal amounts of yellow corn and various combinations of tankage, linseed oilmeal, alfalfa meal, cottonseed meal, fish meal, and buckwheat middlings.

Lots I and II, comparing tankage and fish meal, gained at almost exactly the same rate, and the feed required per 100 pounds gain was almost the same for the two lots. In Lots I and III, comparing linseed oilmeal and cottonseed meal, Lot I gained more rapidly and more economically. This was also true of the comparison of linseed oilmeal and buckwheat middlings as between Lots I and IV.

The results of this trial indicate that tankage and fish meal are nearly equal in value, but that linseed oilmeal is superior to cottonseed meal when used as a part of the protein supplement to corn for growing pigs. Although the results of this trial indicate that

linseed oilmeal is slightly superior to buckwheat middlings, in five out of seven previous trials buckwheat middlings gave more satisfactory results than the oilmeal.

TABLE 3—*Summary of feeding trials with protein supplements for pigs*

Protein supplement	No. of lots	Ave. pigs per lot	Total pig days	Average daily gain (lbs.)	Ave. dry matter per 100 lbs. gain
Tankage	17	9.88	15294.2	1.26	360.14
Wheat middlings	4	9.75	2622.8	1.13	351.63
Buckwheat middlings	4	9.75	3285.8	1.32	348.48
Linseed oilmeal	5	10.00	5630.0	1.26	358.59

CHEMISTRY (AGRICULTURAL)

The work of the department of Agricultural Chemistry is twofold: analytical service for the so-called production departments of the Experiment Station, and research of an original character.

In the course of many experiments with both plants and animals the point eventually is reached where further research is dependent upon accurate knowledge concerning the organic and inorganic constitution of plant or animal matter. Even insect and disease control, to be adequate, must resolve itself into the determination of spray materials of known chemical composition. Thus in multifarious ways chemistry finds itself concerned with plants and animals, their life processes, and their products. Rather than require each department to perform its own analyses of this nature, it has been incumbent upon one division of the station to perform such service on behalf of all departments concerned. The work of the department of agricultural chemistry therefore has included analyses of grains, grasses, silage, feedstuffs, spray materials, fruit buds, fruits, blood, bones, and miscellaneous materials.

The chemistry of bone composition is a case in point. It is known that the proportionate amounts of moisture, ether extract, non-fat organic material, and ash or mineral vary with the type of animal, the kind of bone within the body, the age of the animal, and the condition of nutrition. The extent of this variation is a matter of conjecture. For that reason extensive experiments were begun several years ago to determine the amounts of these ingredients in the bones of hogs, of dairy animals, and of chickens on normal and deficient rations. Later rat bones were included in the study. Six representative bones of hogs — the ulna-radius, vertebra, rib, tibia-fibula, humerus, and femur — were studied. The corresponding bones and the cannon-bone of dairy animals were included, as were also the corresponding bones and the breastbone of the chicken. For the rat the same bones were employed as for the hog. To insure accuracy of results, whole bones were analyzed for moisture, ether extract, and ash content. Calcium, phosphorus, and magnesium determinations were made on certain of these bones.

To date it has been found that the ulna-radius is the least variable of these bones in moisture content and also in ash. A pairing of bones within the same body also is evident. Analyses of many samples show that the humerus and femur, the ulna-radius and the tibia-fibula, and the rib and vertebra tend to pair as far as composition is concerned.

The final aim in this experiment is to reduce, if possible, the rather exhaustive amount of analytical work necessary by learning which part of the skeleton is best adapted for mineral deficiency determinations, and also by determining whether such deficiency may be ascertained from organic symptoms of disease in the animal body, or by other measures, without resorting to the necessity of extensive chemical investigations.

An interesting phase of the function of chemistry in farm crop analysis has come to light in studies with sweet clover. Coumarin is a bitter element which renders this legume objectionable to cows and other forms of livestock. Breeding trials are under way by the department of agronomy and genetics seeking to develop a strain of this clover possessing a low coumarin content. The Obermayer method of extraction with solvents, generally employed for coumarin determinations of this character, proved time-consuming and ill suited to the work in this experiment. Investigations in the department have established a simple technique for coumarin removal through steam distillation, which has proved considerably more rapid and at the same time more accurate.

The intricate process by which apples color as they ripen is the burden of an independent study carried on by the department. The physiological conditions and changes accompanying and affecting pigmentation and ripening are included in this study, the practical application of which, it is hoped, will be to ascertain the actual chemical composition of the coloring matter in apples and the various factors and processes contributing to its formation in the ripening fruit.

A carefully conducted pruning experiment in the department of horticulture, carried on from 1916 to 1930, has afforded opportunity to study certain chemical factors related to kind of pruning (corrective and heavy dormant and early summer pruning), blossom-bud formation, and fruiting. The object has been a study not so much of progressive changes but rather of the apparent relation of certain groups of nutritive substances, including carbohydrates and nitrogen, to kind of pruning, leaf and blossom-bud formation, and fruit bearing.

DAIRY HUSBANDRY

The research program in the department of Dairy Husbandry has necessarily been divided into two fields: that pertaining to the production of milk, and that pertaining to the processed and manufactured products.

In the production field the aim has been to attack the problems in dairy cattle feeding and management that are most important to the West Virginia dairyman. The projects have dealt with problems in nutrition, breeding, and disease control.

In the nutrition of dairy animals it has been felt that one of the largest problems is the lack of sufficient roughage. Each year many tons of hay are shipped into the state, much of which could be saved if crops suitable to West Virginia conditions were grown and their use, with proper supplements, were demonstrated. Many of the projects in the department have been in this field.

Milk can be produced cheaper on pasture than by any other method of feeding. The department has started extensive pasture experiments at the Reymann Memorial Farms. It is hoped that the results obtained from these studies will help the dairyman materially to decrease the cost of milk production.

How best to handle the disease of infectious abortion has been one of the biggest problems in the state. An attempt has been made to develop a method of isolation which can be recommended to the dairymen of the state. One of the largest breeding experiments on the continued use of proven sires is being carried on at the Reymann Memorial Farms.

In the manufacturing field some of the problems confronting dairy plant operators have been attempted. Such problems as the best method of manufacturing rennet-coagulated sweet-curd cottage cheese have been investigated, while studies continue on the bacterial flora of high-grade pasteurized milk, the shipping of cream, and the cause of various flavors in milk and cream.

Part-time Isolation Gives Effective Abortion Control

The method used under this project to control infectious abortion is the isolation of reactors for a period of two weeks before calving and to the end of six weeks after calving.

Testing once each month was accomplished on all animals six months of age or older.

The first isolation was accomplished in June, 1930. At the beginning of the experiment there were 20 reactors in the herd. Reactors have been eliminated from the herd as their economic usefulness ended. Two reactors remain. The size of the herd has been maintained without the purchase of additions on account of infectious abortion.

Only three new cases developed during the progress of the project.

Simplified Rations for Dairy Cows

An experiment seeking to provide the West Virginia dairyman with a simple, economical home-grown ration with which to lower his milk production cost was begun in the spring of 1932 with 14 dairy heifers. A ration consisting of yellow cornmeal, alfalfa hay,

and salt is being compared to a ration consisting of timothy hay and a concentrate mixture of yellow cornmeal, corn gluten, and salt. Check animals of each group are kept in the barn throughout the year, while other animals receive pasture in season. The animals will be carried on through growth, reproduction, and lactation. Various other rations will be studied in this project.

Effect of Low-Mineral Rations on Dairy Animals

Four of the 16 female animals involved in this study have come into milk. One of these belonged to the group receiving a normal-calcium: phosphorus ration; two to the normal-calcium: low-phosphorus group; and one to the low-calcium: low-phosphorus group. Although no significant difference in milk production can be claimed when all factors are considered, yet there has been a noticeable difference in the physical condition of the animals on the abnormal rations as compared to the physical condition of the animals on the normal rations. These animals are being bred again, and will be carried on the experiment until they give birth to the second calf. Each of these cows has given birth to a normal living calf.

Dry Beet Pulp as Good as Wet

In a reversal experiment, the relative feeding value of wet and dry beet pulp for milk and butterfat production is being determined.

Results so far available, would indicate that when dairy cows are given free access to water there is no appreciable difference in the feeding value of wet and dry beet pulp as to the amount of milk or butter-fat produced, palatability, the maintenance of body weight, and the amount of water consumed. It requires considerable more labor to prepare and feed the pulp wet than it does to feed it dry.

Varieties of Pasture for Milk Production

In this study of sweet clover, Sudan grass, oats and Canada field peas, and blue grass as a pasture for dairy cows, certain indications have been observed.

Sweet clover supplied considerably more nutrients than did the other pastures studied. The first year it can be pastured beginning about August 1, even if oats and peas are seeded with it and pastured much earlier. During the second year, very little pasture can be expected from it after August 1. It would seem then that with two fields sown on alternate years, sweet clover would furnish pasture throughout the season. The Sudan grass did fairly well during the first year, but thereafter poor stands resulted, although good stands were obtained on other plots near at hand. This indicates that it may not be advisable to follow Sudan grass with another crop of Sudan.

Flavor in Dairy Products

Buttermilk has a richer flavor than skimmilk and whole milk of equal fat content. The added richness of buttermilk appears to be due to the presence of fat-globule films, a large portion of which becomes disengaged from the fat globules when they coalesce in churning and are left in the buttermilk. The compound in the fat-globule film which seems to contribute largely, if not entirely, to the increased richness of flavor is lecithin. Results of nine controlled trials also indicate that lecithin, which is readily oxidized when purified, oxidizes rapidly in buttermilk also under the conditions obtaining in these experiments, for a "cappy" flavor became evident in nearly all the buttermilks when stored 12 to 24 hours at low temperature. In spite of this cappy flavor an increase in richness of flavor was noted, which indicates conclusively that lecithin in milk and buttermilk contributes to its rich or fat flavor.

Type of Can Affects Cream in Shipment

This study so far has involved methods of shipping cream in less than carload lots. The data collected indicate that the insulated cans are superior to plain, jacketed cans of equal capacity for preventing warming of the cream in transit. Little difference in this respect was found between 5- and 10-gallon cans of similar construction.

In general, bacterial-count increases during shipment were proportional to temperature increases. Mold counts did not change significantly during shipment in any case, but a slight tendency was found for yeast counts to increase when temperature rises were greatest. Acidity and flavor did not change noticeably in any case.

Improvement in Cottage-Cheese Manufacture

Earlier observations that whey acidity at time of cutting the curd is the most important single factor in controlling the manufacture of sweet-curd, rennet-coagulated cottage cheese, have been confirmed in recent studies. Setting temperature, temperature at which skimmilk is pasteurized, amount and strength of rennet extract, and temperature to which curd is heated in the whey, are other factors each of which has a direct bearing upon the production of a clean, firm, palatable cottage cheese.

It is found that the true function of rennin in this type of cheese lies in preventing the matting of curd flakes, while its coagulating properties are of secondary importance. Matted flakes must be broken — a process which results in unsightly, irregular-shaped flakes prone to be rubbery and unpalatable.

To produce the most desirable curd the proper balance must obtain between rennin action and acid development. As much rennet-extract as possible should be used in order to reduce matting to a minimum. The amount to be used will be determined by the

strength of the extract and the cutting acidity selected, and is the amount just below that which causes curd disintegration on stirring.

The temperature to which the curd is heated in the whey governs the firmness and character of the curd resulting from each set of setting and cutting conditions. For skimmilks pasteurized at 145°F. and set at 90°F., desirable firmness is attained usually at from 120-135°F.

A setting temperature of 90°F. was found preferable to one of 70°, since rennin and acid-producing bacteria act faster at the higher degree, and so permit of a shorter making time. Pasteurizing temperatures of 165° and 185°F. yielded a softer curd more prone to shatter and break on stirring, and less easily firmed, than that from skimmilk pasteurized at 145°F.

Effect of Pasteurization on Bacteria in Grade-A Milk

Since the previous report on this project a second study of the efficiency of pasteurization for 74 samples has been made in which a greater efficiency was shown for low-count raw milks than was found in the previous trial. This result was attributed largely to the fact that the packing of the vat agitator which was slightly leaky during the first trial was in good condition during the second trial. It was found possible to destroy by pasteurization at 145°F. for 30 minutes more than 99 percent of the bacteria in the 74 deliveries of low-count milk produced by the station dairy herd under controlled conditions.

Results previously obtained, showing a decided increase in the proportion of acid-forming and a decrease in acid-coagulating organisms, were confirmed.

In further tests of the keeping qualities of high-grade milks before and after pasteurization a tendency was found for the proportions of peptonizing organisms to decrease during a four-day storage period at temperatures ranging from 36° to 56°F. Neither the raw nor pasteurized milks showed marked changes of percentage of acid-coagulating organisms on storage at any of the temperatures used, whereas the percentages of acid-forming bacteria were more variable though exhibiting no definite general trend.

ENTOMOLOGY

With the limited staff available for research, work in the field of entomology is necessarily restricted. Projects in progress are of two general types: studies which may have more or less immediate practical value and studies which are of a more fundamental nature and which may be expected to develop practical applications only after more protracted periods. In the latter class must be included the departmental project dealing with the effect of climatic factors on insects. One of the important ultimate objectives in this project

is to determine how to foretell, through knowledge of the development of insects and their natural enemies under different climatic conditions, the probable abundance of injurious species. Long-time studies of hibernation, behavior of insects under different conditions of drouth, excessive moisture, extremes of temperature, and normal conditions may furnish the desired information.

Determination of the most effective time for the application of spray and other treatments for insect control is already accomplished, at least in part, by the utilization of facts obtained through the studies of the temperature relations of insects, and progress seems certain along this particular line.

Projects of a more immediately practical nature are those dealing with the life history and biology of pests attacking the crops of the state. Such a study has been that of the pistol-case bearer and of other orchard insects as well as pests of other crops such as the Mexican bean beetle.

Insect control practices are constantly being modified and improved, either by the development of new methods or by the use of new materials. Studies, particularly of new insecticides which may be of value for our pests, are imperative since local practices and conditions often determine whether materials are suitable or not. Investigations of materials such as the various fluosilicates, pyrethrum products, tar-oil derivatives, and several less important products take up a considerable portion of the time available. The application of insecticides, methods, and accessory materials as adhesives must be considered along with the work on insecticides themselves and is receiving attention. Related work has to do with arsenical residues and with tree-banding materials.

Minor insect outbreaks and means for preventing damage from them must be considered from year to year. Problems of insect distribution, especially that of potentially important species, are correlated with the experimental work.

Adherence and Distribution of Arsenical Residues

Weather and rainfall have surprisingly little effect on the amount of arsenical residue on fruit in work done at the University Experiment Farm at Kearneysville. Any reduction in the amount of residue per pound of fruit is found to be due to the growth of the apple rather than to loss of arsenic. In the process of growth a certain amount of residue becomes detached and lost, independently of weather conditions, for sheltered fruits show nearly as much loss as those exposed.

Arsenate of lead alone adheres to fruit better than does the same material mixed with bordeaux, lime, "glutrin," "goulac," or "ferroskim." The only adhesive which increased the residue was fish-oil. Fruit from the lower limbs showed 66% more residue than that from the upper branches.

A definite correlation is seen between the amount of residue in different parts of trees and the infestation of codling moth in those parts.

Pistol-Case Bearer Control

The pistol-case bearer is an insect which has increased in abundance during recent years to such an extent in certain orchards in the Eastern Panhandle that it may be said to rival the codling moth in potential destructiveness. It has been found very difficult of control; so far the usual spray program, even with modifications of the materials used, has failed.

Various enlargements of a group of cocoons on a twig

A degree of control which at least prevents the increase of the insect in abundance has been obtained by the use of a combination of nicotine sulphate at one part to 800 parts of water with one-half percent penetrol, applied just after the hatching of the eggs in July. The utmost thoroughness in the application of this material is necessary if a satisfactory degree of control is to be obtained. Some of the new tar-oil sprays seem to promise winter control.

It is recommended that special sprays to keep down the numbers of the insects be applied in orchards where it seems to be increasing, even though not yet present in destructive numbers.

Further work in the development of new control methods and materials is in progress. (Bul. 246.)

Control of the Apple Aphids

Studies looking toward control of the apple aphids, which must be considered among the most important insect pests of this fruit, have dealt with coal-tar products. These have included emulsions of tar-oil distillates prepared by commercial firms, and similar emulsions prepared for the tests with various emulsifying materials, as

well as several coal-tar derivatives. Results indicate that the tar oils, and especially certain fractions thereof, will kill aphis eggs during their dormant season and may thus afford the apple grower a more satisfactory means of control than has hitherto been available. Cresyllic acid preparations seem to be the best materials so far developed. However, the higher strengths of the tar-oil emulsions, according to laboratory tests, may retard bud development and even kill the buds. Recommendations must therefore be made with considerable caution.

Laboratory and field tests of the fractions of tar oil show considerable variation in killing power and in their effect on the trees, especially on the developing buds.

Results with the San Jose scale were much less definite than results with aphid studies. It is possible that a combination spray may be required if both insects are to be controlled at one operation.

The Weather Factor in Insect Control

The department for a number of years has carried on investigations concerning the effect of temperature and other climatic factors on the development and behavior of orchard insects. The following new facts have been recorded:

The bean beetle has no fixed hibernating habit, studies made over a period of years would indicate. The insect spreads in search of food and becomes inactive with the advent of cold weather. Extremely cold spring weather following an otherwise mild winter in 1931-1932 maintained beetle mortality around the usual 90% mark.

Rosy aphid may at times remain semi-active on plantain until February or March, when late migration to apple may occur and result in unexpectedly high orchard infestation. Exceedingly high mortality of San Jose scale resulted from severe March freezes in 1932.

Many apple aphids perished from lack of available food at hatching time during erratic weather in early spring of 1932.

Studies of the hibernation of the codling moth lead to the conclusion that temperature records may furnish an idex for spraying operations which will be just as reliable as the observations of emergence of moths in cages and at much less trouble and expense.

An unusual outbreak, in the spring of 1932, of the grass webworms of several species is correlated with the high minimum soil temperatures recorded for the preceding winter and suggests that warnings based on soil temperatures of similar range, furnished to the farmers, may be of distinct service in the future.

Control Measures for Garden Insects

Practical control of the Mexican bean beetle seems now to be a problem of education rather than of experiment, since definite measures of control have been developed which are at once effective and economical.

Barium fluosilicate is a valuable addition to the list of poisons as it is slightly quicker in its action than the other fluosilicates. This material and the other fluosilicates used are comparatively nontoxic to man and should replace arsenical sprays when the beans have formed on the vines.

With certain restrictions, pyrethrum is entirely satisfactory. This insecticide is comparatively high in cost, and the fact that it is a contact poison reduces its value where neighboring gardens are left unsprayed.

Three species of common native ladybugs, two stinkbugs, and one assassin bug have been studied in field and laboratory. Indications are that all these may become effective aids in the control of the bean beetle.

FARM ECONOMICS

The work of the department of Farm Economics is designed to point out weaknesses in organization, management, and marketing as related to agricultural production, with the object of formulating recommendations for changes which will result in greater efficiency and economy.

The investigations of the department during the biennium have consisted chiefly of studies of orchard management, livestock production and marketing, wool and egg production, land utilization, and orchard spraying. Two of the projects are being carried on cooperatively with other states and the U. S. Department of Agriculture. Of these projects only the study of land utilization was begun during the biennium. The adjustment of use of land to climate, soil, and economic conditions in the Huntington area has been undertaken in cooperation with several of the departments of the Experiment Station. Particular attention is being given by this department to returns from farming as practised in the region. The solution of land utilization problems in this area seems to lie in a change in the type of agriculture and farm organization.

West Virginia is essentially a livestock state. Cost data and methods of marketing form the basis of the selection and combination of livestock and crop production. Through cost studies farmers learn how to produce more economically and market more efficiently. An analysis of cost of production and prices received by farmers for livestock grown and marketed in different ways has pointed out the weak and strong points in the handling of livestock. The study of farms on which fine-wool sheep and poultry are important enterprises tends to show the place and outlook for these products on West Virginia farms.

Studies of factors governing the production and marketing of apples in the Eastern Panhandle have been completed. The study in orchard management covering a period of three years which is almost finished will complete the work on the orchard project.

Closely related to this is the study of hydrant spray systems which has been in progress for three years.

Trends in Fine-Wool Sheep Production

The field work of this project, concerning the status, trends, place, and outlook of the fine-wool sheep industry in the northern part of West Virginia, begun three years ago in cooperation with Pennsylvania, Ohio, and the U. S. Department of Agriculture, should be completed in the fall of 1932. Results of the past two years' records would indicate that fine-wool sheep production has not been very profitable from 1929 to 1932. The low price of wool has materially changed the method of managing the flocks of 38 cooperators. This change is from wethers to more ewes and, in a large number of cases, the raising of cross-bred lambs. This system gives the sheep producer two sources of income — wool and lambs. It increases expenses for feed, but incomes are increased in a much greater proportion.

Flocks having a high weight of fleece, medium amount of grain and roughage, and good management in the way of shelter and treatment, are found the most profitable. Lack of adequate control over stray dogs and lax enforcement of the dog-license tax have resulted in heavy sheep losses and small returns in some flocks. Complete results of the study with recommendations will be published in 1933.

Profits in Poultry Management

This project was started with 40 poultrymen in the Parkersburg area in February, 1931, with the assistance of the Agricultural Extension Division and the Poultry Producers' Cooperative Association. Results indicate that poultry was one of the most profitable enterprises on these farms in 1931. Improved management methods and better-producing hens have resulted from the marketing and record work being done in this area. Poultry clubs have been organized in two counties. Continued work on records and flock management should help increase poultry flocks and profits.

Land Utilization in the Huntington Area

A comprehensive investigation of the diversified agriculture of a large section of the state was instituted in the spring of 1932. The Huntington area, comprising the counties of Wayne, Cabell, Putnam, Lincoln, and Mason, was chosen. Five factors were involved in this study, in which practically all departments of the Experiment Station were engaged, as well as the Agricultural Extension Division. These include the physical factor, the organization of the farm as a factor in the return of profits, the status of marketing and of markets, and the human or management factor. About 225 farmers, representing the predominating ten types of farming in the area, are cooperating with the fieldman in keeping

cost account records. In addition, labor income records were obtained from 453 farms.

Economic and Social Problems of the Highland Area

In a comprehensive economic and social study of the Southern Appalachian highland area, begun in 1931, the Experiment Station is cooperating with the U. S. Department of Agriculture and the U. S. Department of the Interior in so far as the highland sections of this state are concerned. Available geographical, statistical, and descriptive material is being utilized to determine the major facts concerning the nature, extent, and importance of the economic and social problems of the West Virginia highland area. The study indicates that a large number of families living in the mountainous area of the state are making very small incomes. Social conditions are anything but good. The question of what can be done to improve both social and economic conditions among these people is receiving careful consideration.

Land-Utilization Study of Nicholas and Webster Counties

The most economic utilization of the land resources of a mountainous state such as West Virginia is one of the major problems confronting the agricultural program of a commonwealth. An investigation was carried out in cooperation with the Bureau of Agricultural Economics of the U. S. Department of Agriculture in Nicholas and Webster counties, typical of a large area of the state. One objective was to show which type of land should be used for agriculture and which for forestry, and to point out the conditions which might determine whether land not easily classified as farm land or forest land should be employed for another type of farming or for a different combination of agriculture and forestry. A second objective was to suggest avenues of improvement in the utilization of both farm and forest lands, and the relation of such changes in utilization to the social institutions of the area, particularly the schools and roads. The study with its recommendations is reported in Technical Bulletin 303 of the federal Department.

Orchard Management Studies

A study of orchard management and of the place of orchards in the farm organization in the apple section of eastern West Virginia has revealed that entirely too many varieties of apples are grown in this region and points to several leading varieties which are very promising and from which growers are making good returns. Spraying is being done reasonably well on most orchards and is showing results where properly applied.

There are real possibilities for improving the work in general by proper distribution of labor, eliminating unprofitable varieties, spraying at the proper time, marketing the product soon after harvesting, and by the use of proper equipment for all orchard work.

Orchards can be divided as units, and equipment provided to fit each unit. Methods of financing orchards are not satisfactory. A number of growers are learning the value of economy in performing the various operations at the proper time. A definite operating statement is being worked out for each individual orchard.

Grading and Packing Hold Key to Profits

Many production problems in the apple-growing region of the Cumberland-Shenandoah valleys are still unsolved. A study of one of the more pronounced of these problems, that of marketability, was undertaken during the years 1924-27 by the experiment stations of Pennsylvania, Virginia, and West Virginia in cooperation with the Bureau of Agricultural Economics of the U. S. Department of Agriculture. It was found that the marketing problem in this region resolves itself into a consideration of the national status of apple production as well as of the most advantageous methods of merchandising the crops grown locally.

There is need for close attention to those points of orchard practice which result in a high percentage of unblemished fruit. Strict and uniform grading and packing are imperative if eastern growers would successfully meet the competition of western apples, which are sold in this region in attractive containers. Storage is recommended as a means of extending the marketing season and so of enhancing the possible returns to the grower. (U. S. D. A. Tech. Bul. 234.)

Deep Tillage for Field Crops and Orchards

Work on a project to determine the value of deep tillage for field and orchard crops, begun in the fall of 1931, is being carried out on the University Experiment Farm at Kearneysville in cooperation with the departments of horticulture, agronomy, and the University Experiment Farm.

Paired plats are being used in the study with potatoes, corn, and alfalfa in a four-year rotation. All plats are in quadruplicate. The effect of deep tillage is being measured by yields and by moisture determinations, the latter being taken at regular intervals throughout the season.

Objectives of the study are to determine the value of deep tillage as it affects crop yields and to ascertain the effect of deep tillage upon the water-holding capacity of the soil.

Stationary Spray Systems

A three-year study of the stationary system of orchard spraying in comparison with the portable system in common use has now been completed, and final data have been assembled for publication. A number of plants operating in West Virginia have been studied to determine the advantage of such factors as capacity of pump, sizes and kinds of pipe, length of lead hose, number in spray crew,

and the like. Detailed costs of power, materials, and labor have been recorded. Because of the wide range of conditions and of management obtaining in the different orchards no general recommendations can be made, but the fruit grower who considers the installation of a stationary system can determine its advantages, costs, and the best management practices from a study of the data. Observations covering two years of the study were published in Bulletin 239 of the Experiment Station, and complete data on recent studies will be available in the near future.

In comparing disease and insect control the stationary system is found to be very efficient in trees from 15 to 20 feet high, but ineffective spraying, especially where codling-moth infestation is severe, may result in the upper parts of taller trees.

Cooperative Marketing of Livestock

To examine the efficiency of cooperative shipping associations in West Virginia as livestock marketing agencies, to evaluate their accomplishments, and to locate factors of inefficiency, the elimination of which would make such associations more effective agencies for marketing livestock, a study was undertaken by the department of such associations in the state operated within the years 1924-29. This study embraced a view of the history of the movement in West Virginia, the plan of organization, the aims, the costs of marketing livestock cooperatively, and a comparison of independent dealers' and cooperative prices. These data are set forth in Bulletin 249 of the Experiment Station.

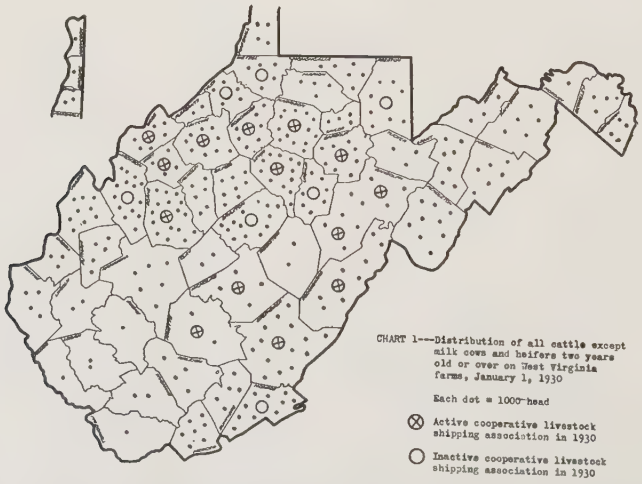


CHART 1--Distribution of all cattle except milk cows and heifers two years old or over on West Virginia farms, January 1, 1930
Each dot = 1000 head
Active cooperative livestock shipping association in 1930
Inactive cooperative livestock shipping association in 1930

It is concluded that the marketing costs of the shipping associations were greater than necessary for maximum efficiency. The key to lowering these costs is larger volume and better management. The cooperative has an incentive, not felt by the independent deal-

er, to improve the quality of livestock, for with costs as they are the price received by the producer is dependent upon the terminal market price. The work of the cooperatives in the improvement of this quality is perhaps their greatest achievement. Yet the work, just begun, cannot become fully effective until a larger part of the producers patronize these associations which pay according to quality.

HOME ECONOMICS

The Protective Function of Vitamin A in Infection

Vitamin A, the anti-infection vitamin, can be present in the diet in considerable amounts without preventing middle-ear infection. Infections of the sublingual gland, however, seem to occur only on diets entirely lacking in vitamin A, according to experiments with white rats.

In the infections characteristic of vitamin-A deficiency the adrenal glands of rats show changes in their content of water and cholesterol which may prove of significance in immunity.

Syrup of ferrous iodide has been found to have no substituting value for vitamin A in preventing loss of weight, xerophthalmia, middle-ear infections, or death in rats on vitamin-A free diets.

Histology of Bone Growth in Vitamin Deficiency

Evidence derived from studies with 20 rats would seem to indicate that the enlargement of the joints generally reported as occurring in rickets may prove to be apparent rather than actual and due to failure of certain phases of normal bone growth. Significant changes are brought about in the bones by additions of even minute traces of vitamin D in the form of irradiated ergosterol which will help to clarify the method by which rickets is healed.

Studies of blood chemistry of a limited number of human subjects indicate that there may be an adult need for vitamin D as important as that necessary to prevent rickets in children, the need to improve calcium-phosphorus metabolism.

Uses for Surplus Food Products

Studies in the economic utilization of surplus food products on the farm have resulted in: I. Determination of the cause of spoilage of vegetables canned by farm women as a sale product in gallon tin cans; II. The working out of an economical and satisfactory method of making blackberry jam for sale through the Home Industries shops of the state and for home use. This investigation has brought out the following practical points for improving the quality of the product and preventing loss through poor results:

1. A simple test for pectin content has been put in the hands of housewives and made to show the correct amount of sugar to be added to blackberry jelly or jam for maximum yield and best consistency without waste.

2. The commercial practice of cooking jelly and jam by weight has been adapted to home use for blackberries, and a table of weights has been worked out for the ordinary quantities used. This has proved simpler to use and more uniform in result than cooking jelly or jam to temperature as first recommended.

III. Improvement in the method of making cherry preserves along lines similar to those used under No. II (above).

HORTICULTURE

Research with horticultural crops at the Experiment Station has a twofold aim: first, the testing of new crops, new varieties, and variety strains of fruits and vegetables to determine their adaptability to the diverse conditions of soil and climate found in West Virginia. Among the new fruit crops being studied are pecans and Persian walnuts, among the vegetables broccoli and Chinese cabbage. Hundreds of new varieties of fruits and vegetables also are being tested. Variety strains among such vegetables as tomatoes, cabbage, and potatoes are often more distinct than the varieties themselves, especially as regards earliness, quality, and productivity. Many are being grown at the Lakin Experiment Farm to find out which are best for that trucking region. Much attention is being given to color sports of our standard varieties of apples, as they seem destined to supplant the varieties from which they have sprung.

An apple orchard in bloom

The second aim of research in this department is the determination of the cultural and fertilizer requirements of the various horticultural crops to the end that a quality product be produced as economically as possible. A few of the important investigations along this line may be mentioned. Various nitrogen fertilizers are being studied to determine which is the best and most economical for the orchardist to use, and their effect on the keeping quality of the fruit

produced. The building up and maintenance of fertility in the orchard and truck garden is of great importance particularly on the shale soils of the Eastern Panhandle and on the sandy bottoms of the Ohio river. In the study of this problem the crop rotations most adapted to the region are being investigated as well as different kinds of cover crops, all with and without different types and amounts of fertilizer. The thinning of fruits markedly affects their quality. With the growing demand for a high-quality product come problems such as time and severity of thinning for the standard commercial varieties of apple and peach. Studies are being pursued to throw light on these questions.

Pollenizers for Northwestern and Rome

In a continuation of apple pollination studies the varieties Northwestern and Rome were found to be practically self-sterile. Pollen from Starking, Red Rome, Lowry, York, Jonathan, and Delicious gave good sets on Northwestern, while King David, Northwestern, Golden Delicious, Jonathan, Starking, and Lowry proved to be good pollenizers for Rome. Red Rome also gave a poor set on Rome.

Apple Storage as Affected by Nitrate and Maturity

Data obtained in Eastern Panhandle orchards indicate that the increase in the amount of scald from nitrogen fertilization probably is due largely to delayed maturity of the nitrated fruit rather than to the presence of more nitrogen in the apple. Yorks picked on Oct. 6, about a week before the peak of commercial harvest, scalded severely regardless of whether the trees had been nitrated or not. Fruit picked a week later (October 14) showed very much less scald, although it was still high in the fruit from nitrated trees. In fruit picked October 21 (a week later than the peak of commercial harvest) there was still further decrease in scald, the fruit picked from nitrated trees at this time developing less scald than fruit from check trees picked two weeks earlier, although the nitrated fruit was still rather green in color. It is important, therefore, that harvesting of scald susceptible varieties such as York, Grimes, Black Twig, etc., be delayed as long as possible, and especially so in nitrated trees.

TABLE 4—*Scald development of apples in storage experiment, 1931-32, with York Imperial (5 trees in each treatment)*

Treatment	Date picked	Total no. apples	No. sound	No. scalded	Percent scalded
Check—without oiled paper	Oct. 6	562	98	464	83
Nitrated—without oiled paper	Oct. 6	494	75	419	85
Check—without oiled paper	Oct. 14	564	262	302	54
Nitrated—without oiled paper	Oct. 14	397	111	286	72
Check—without oiled paper	Oct. 21	341	230	111	33
Nitrated—without oiled paper	Oct. 21	680	322	358	53
Check—with oiled paper	Oct. 14	739	611	128	17
Nitrated—with oiled paper	Oct. 14	658	513	145	22

The data, taken eight months after the fruit was picked, are given in Table 4. The marked reduction in scald as a result of using

shredded oil paper — from 54% to 17% in fruit from check trees without nitrogen, and from 72% to 22% in fruit from the fertilized trees, may also be noted.

Nitrogen Sources for Apple Trees

Four fertilizer experiments comparing nitrate of soda and sulphate of ammonia with apple trees were conducted between 1922 and 1927 in different apple-growing sections of the state. In Pleasants county early applications of both fertilizers on 32-year-old Rome trees were found superior to those made at bloom. Nitrate excelled sulphate when both were applied at bloom. Nitrate also proved superior in both growth and fruitfulness on 9-year-old Jonathan trees in Berkeley county fertilized at bloom. In Jefferson county in a 25-year-old Black Twig orchard no differences in growth of trees were observed between the two fertilizers when applied two to three weeks before bloom, but significant differences in yield were obtained in favor of sulphate of ammonia.

It is concluded that the choice between the two fertilizers should be determined by their relative cost in terms of nitrogen units. To insure full value from sulphate of ammonia it should be applied at least two weeks before bloom and should be worked into the soil where early cultivation is being practiced. It should be borne in mind also that eventually lime must be applied to correct the acidity of sulphate particularly if legume cover crops are grown. (Bul. 252.)

Cover Crops for Apple Orchards

Tests were begun in 1927 in a commercial apple orchard at Paw Paw of clean cultivation, alfalfa, sweet clover, and mixed-grass sod. Additional nitrogen has been added to trees in all plots. Results to date as measured by growth and yield indicate that sweet clover and alfalfa are best.

Good Culture Prevents Winter Injury in Peach

Great losses result annually by freezing injury to the fruit buds of peach, plum, apple, cherry, and other fruit trees. The peach is particularly subject to damage by freezing and it is not uncommon to lose a season's crop because of death of the fruit buds by low temperatures. Besides, the floral organs may be killed by freezing temperatures when the trees are in flower.

The killing of fruit buds during the dormant period varies with the variety. Experiments were conducted over a three-year period on the influences of cultural practices and other treatments on the hardiness of two varieties of peach tree — Salwey and Greensboro. The results of these studies suggest some procedures that should be followed in peach-orchard management in order to obtain the maximum resistance of the buds to winter injury. Since the greatest degree of hardiness was found in cases with the greatest storage of food reserves, it follows that a large and healthy leaf area should be maintained late into the fall. This can

be accomplished by judicious cultivation, pruning, applications of nitrogen, and the adequate control of insects and disease.

Cultivation or the application of nitrogen-carrying fertilizers should be made early in the spring to stimulate a quick growth of the trees and to produce a thrifty leaf area. The trees should be pruned in the dormant season and this should be of such moderate severity as to regulate the bearing area without producing a vegetative condition of the trees. Over-bearing of the trees should be avoided by proper thinning of the fruit. (Bul. 236.)

A view of the sour-cherry pruning block

Moderate Pruning for Early Growth and Yield of Cherries

In recent years considerable interest has been taken in the production of sour cherries for canning purposes in the Eastern Panhandle. In order to study the relations of pruning to the growth and yield of sour-cherry trees an experiment was undertaken at Morgantown in which varying degrees of dormant and summer pruning were employed. (Bul. 240.)

The conclusions derived from the experiment show clearly the severe dwarfing effect of summer pruning and heavier-than-corrective dormant pruning on tree growth. Such reduction in tree growth as well as in yield of fruit following summer pruning apparently is due to the removal of the leaves before they have made their contribution to the food supply of the tree. The circumstance would emphasize the great importance of maintaining during the summer and early fall the maximum area of leaves capable of functioning photosynthetically.

Young correctively pruned sour-cherry trees make more shoot growth and larger gains in trunk diameter, come into bearing earlier, and produce heavier crops than similar trees more severely pruned.

A new series of treatments of Montmorency cherry trees, involving four degrees of severity in pruning young trees, has been begun on the University Experiment Farm at Kearneysville.

A training experiment on newly-planted trees of four varieties of apples has for its object a comparison of debudding with standard practices of starting the young tree.

Seed Potatoes Can be Grown in West Virginia

In order to determine the feasibility of seed-potato production in certain of the upland areas of West Virginia, seventeen trials were carried on during three years at four altitudes in the state and at two latitudes outside the state — at the Kentucky and Minnesota Experiment Stations — in which the yields of two native strains of Smooth Rural seed potatoes and a recommended strain of the same variety from the North were compared. (Bul. 242.)

The native strains equaled or bettered the northern strain in yield in the plantings made in West Virginia. The altitude at which the trials were run usually determined which of the native strains proved superior. Usually the high-altitude and northern-grown stock gave higher yields at the higher altitudes, even as did the low-altitude strain in trials at the lower altitudes.

It is concluded that it is feasible to produce seed potatoes in the medium and probably the high altitudes of the state.

Normal Storage Best for Potato Seed

No difference has been discerned in respiration studies of Rural seed with normally-stored stock and stock greened in the fall, but plantings at Reedsville have shown the normally-stored tubers to be superior as seedstock to either fall-greened or sun-sprouted stocks. Experiments with Cobblers show that warming the seed gives quicker come-up and more vigorous young plants, but results in no differences in yield.

Better Varieties of Vegetables

A series of field trials with several vegetables at the Lakin Experiment Farm shows, among early varieties of sweet corn, Vanguard as a vigorous, heavy yielder with large, white, well-filled ears of good quality. It is moderately early and perhaps more resistant to bacterial wilt of corn than any other variety tried. Whipples Early Yellow, Whipples Early White, and Extra Early Bantam are other high-yielding and early varieties.

John Baer, Penn State Earliana, Bonny Best, and President proved to be desirable varieties of early tomatoes. Break-O-Day, a new variety, shows every advantage except susceptibility to sunscald, a result of its branching habit of growth.

Among early beet varieties the following proved superior: Early Wonder, Crosby's Egyptian, Extra Early Egyptian, Improved Early Egyptian, Eclipse, and Detroit Dark Red. Early Wonder is particularly of value for canning because of solid red color and earliness. These strains were high in quality and of uniform appearance.

Early cabbage strains of particular promise are Golden Acre, Copenhagen Market, New Early Krop, and Early Market.

Particularly adapted for early bunching purposes among carrots are Danvers Half Long, Early Chantenay, Red-Cored Chantenay, Orange Danvers, and Oxheart.

Among eggplants Black Beauty, New York, and Excelsior compared closely, and Ruby King and California Wonder varieties of pepper seemed to do best. Bender's Surprise proved superior in many respects to Tip Top, a standard muskmelon variety.

Paper Mulch Has Decided Limitations

At Morgantown mulching as compared with clean culture has resulted in earlier yields of eggplant, greater suckering of sweet corn, greater yields of marketable beets and carrots, and greater number and total yield of tomatoes, peppers, and eggplants. These increases, however, were so markedly reduced by the increased occurrence of sunscald, soft rots, blossom-end rots, etc., that no marked influence was noted on the number and weights of marketable fruits. With nearly all vegetables used, mulch paper gave greater plant growth.

The comparison of black and white papers with the pepper showed no significant differences, although white paper appeared to be more beneficial. Black paper treatment resulted in more sunscald and tissue breakdown.

Soil moisture studies showed the amount of water to be greatest under the mulch at nearly all times during the season.

Hydrogen-ion concentration and the amount of nitrate nitrogen in the soil were apparently not influenced by the mulch paper.

Temperatures were higher under the mulch; there was a considerable time lag as compared with the air temperatures. The temperatures were higher by a few degrees under the black paper than under the white.

At Lakin the mulch had little effect on beets, proved detrimental to early cabbage and eggplant, and slightly increased the yields of marketable peppers and staked tomatoes, although it significantly increased the number of fruits affected with blossom-end rot. Mulch produced more suckering on sweet corn.

White paper proved to be better than black paper on peppers, although the differences were slight. Black paper resulted in a small increase in the amount of sunscald. These results are in line with those obtained at Morgantown, although the differences are less marked.

The results indicate that there is some doubt as to the practicability in the use of mulch paper for any of the crops used in these studies under West Virginia conditions.

Deep Tillage and Explosives for Orchard Soils

The possibilities of making orchard soils more productive by dynamiting the subsoil are being investigated at Morgantown and on a commercial orchard at Romney. Small charges of dynamite are placed 2 to 3 feet below the soil surface, a few feet from the base of the apple trees, and exploded to loosen the subsoil. In other orchards the subsoil is broken up by means of a subsoiler,

which bears a long tooth capable of breaking up the soil to a depth of 18 to 20 inches.

Trees on thin soils suffer severely in periods of drought because their roots cannot penetrate deeply enough to reach the moisture. The value of deep tillage will be determined by measuring comparative results on the basis of trunk circumference growth as well as twig growth and by yield and size of fruit of treated and untreated trees. A phase of the experiment concerns the effect of deep tillage on a rotation of alfalfa, corn, and potatoes.

PLANT PATHOLOGY

As agriculture becomes more intensive the diseases of plants and animals become more important. Fruit and vegetables were grown successfully without spraying or other protection a few generations ago, but today apples must be sprayed systematically and thoroughly in order to obtain any high-grade fruit. The diseases of potatoes have become so serious that at this time they are the most important single factor in potato production. This situation is developing with other crops of the field, garden, and forest to such an extent that it has been predicted that the most serious problem of the future agriculturist is that of controlling parasites.

The aims of the department of Plant Pathology are twofold: to study the diseases of West Virginia crops and plants, and to make public the information thus gained as well as pertinent information received from investigators in other institutions within our borders or in other states and countries.

The department is well equipped and supplied for all phases of investigations in which it is now engaged. The chief problems now engaging the staff are those dealing with the diseases of apples, truck and field crops, and tree diseases. These investigations have been assisted materially by facilities provided at the University Experiment Farm, Kearneysville, Reymann Memorial Farms, Wardensville, Lakin Experiment Farm, and in numerous private orchards throughout the state.

Some nineteen bulletins of the Experiment Station dealing with plant diseases have been published in full or in part by members of the staff. In addition nine circulars of the station and two circulars of the Extension Division have been issued as well as 20 technical articles in scientific periodicals.

Studies of the Watermelon-Wilt Fungus

The breeding phases of this problem are being conducted in cooperation with the department of Agronomy and Genetics. Extensive field tests are being made with crosses between the resistant Russian and two commercial varieties of watermelon grown in the Ohio valley.

The pathogenicity of the 23 isolants of *Fusarium niveum* from different localities of the United States varied with the resistance

of the suscept, but all of the varieties and hybrids tested were found to be somewhat susceptible to the most virulent isolants of the wilt organism.

From wilted plants growing in separate boxes of soil infested with individual isolants, dissociants were recovered which in two cases (isolants #11 and #16) were identical with dissociants obtained in petri-dish cultures of these same isolants. Dissociation therefore can take place in the soil and presumably is a common phenomenon with this organism in nature.

Cuttings of melon seedlings placed in a filtrate of *F. niveum* wilted in eight hours under laboratory conditions, but when such cuttings in the filtrate were placed under a bell jar no wilting occurred in 72 hours. This indicates that the wilting effect probably is not caused by a toxin of the parasite.

TABLE 5—*The pathogenicity of various isolants of Fusarium niveum**

Isolant	Number of plants	Number of plants wilted	Percentage of plants wilted
1	396	353	89
2	311	143	46
3	287	276	96
4	392	345	88
5	330	122	37
6	307	273	89
7	274	127	45
8	309	272	88
9	272	62	23
10	335	7	2
11	297	291	98
12	278	8	3
13	328	0	0
14	322	0	0
15	321	0	0
16	320	266	83
17	315	3	1
18	302	0	0
19	326	0	0
20	331	331	100
21	297	0	0
22	320	0	0
23	321	247	77
Check	315	0	0

*Plants approximately 21 days old and grown in infected flats in greenhouse.

Spray Materials for Apple Disease Control

Striking differences in the quality of the finish of apple fruit were noted from the application of different fungicides to be used as substitutes for lime sulphur, which under certain weather conditions causes severe burning of both leaf and fruit. In the order of excellence of finish the fungicides tested ranked as follows: dry-lime sulphur, calmosul, flotation sulphur, lime sulphur.

Suspension tests of 30 formulae indicate that instant Bordeaux prepared from superfine chemical hydrate and pulverized copper sulphate, properly combined, gives a higher suspension than Bordeaux prepared from the finest grade of pebble lime obtainable. Concentrations lower than 2-4-50, the formula in general orchard use, have been found toxic to bitter-rot spores.

Fruit Spots of the Apple

In 1930 an investigation was begun on Brooks Fruit Spot and similar diseases of the apple. An examination of overwintered apple leaves in several orchards revealed an abundance of *Mycosphaerella pomi,* the perfect stage of *Cylindrosporium pomi.* No evidence was found that the perfect stage is present on the fallen leaves of any unrelated genera and species of trees.

A series of inoculations was made on mature fruits of 12 varieties during the fall of 1931. Grimes varieties were found most susceptible to infection by two species of Penicillium and an Alternaria, with Delicious, Golden Delicious, McIntosh, Wealthy, and Jonathan next in susceptibility. York, Stayman, Winesap, and Baldwin were the most resistant.

The Cause of Apple Measles

Discovery of the cause of the papular type of apple measles has definitely been verified. Successful artificial inoculations have been obtained on young Red Astrachan trees in the greenhouse during the winter of 1930-31, and the fungus was readily reisolated from the lesions produced. The fungus has been identified as a Hyphomycete showing affiliation with the genus Endophragmia, which bears cup-like membranes at the nodes of the conidiophores.

A survey of the important apple-growing sections of the state has disclosed that a second type of measles known as the "blister type" and peculiar to the Delicious and related varieties is becoming more important each year and is causing considerable concern to growers who have planted these varieties. Young plantings have shown a higher percentage of infected trees than old plantings. A third type of measles, characterized by producing very numerous pimples, smaller than those in either of the other two types, has been found to be fairly common on York, Jonathan, and Rome.

Collar Rot of Apple Trees

In an investigation of the Grimes collar rot and similar diseases of the trunk, collar, and roots of apple trees, grafting work has been completed with Grimes scions on three different stocks: French crab, Vermont crab, and Grimes stocks. These trees will be used this coming year for experiments with low temperatures under controlled conditions.

The other phase of the problem has to do with survey and isolations from diseased roots and crowns. A number of cases of Xylaria root rot have been found in the eastern part of the state and half a dozen cultures of these obtained. Every culture from different sources is different in appearance. All produce fructifications but without maturing perithecia in culture.

Several basidiomycetes have also been isolated, one of which, an agaric, produces very small sporocarps in pure culture. It is planned

to use all of these organisms for inoculation studies beginning in the fall of 1932.

Apple Rust

Much time has been devoted to grafting scions from resistant and susceptible red cedars on red-cedar and Biota seedling stocks. It appears that Biota is preferable to red cedar because it develops callus tissue rapidly, and consequently the graft union is more likely to succeed. More than 100 such grafts of both resistant and susceptible red cedars will be exposed for rust infection to determine their susceptibility or resistance.

The phase of the study that dealt with the susceptibility of apple varieties to rust has been concluded. Sixty-six commercial varieties were included in the test orchard, and data on rust infection have been recorded for a number of years. Marked differences exist, some of the varieties being practically immune and hence suitable for planting in localities where cedar removal is impracticable.

Typical catface caused by canker

Black-Walnut Canker

It has been established by survey methods that black-walnut canker, a disease of recent discovery, is present in 28 counties in West Virginia. It has also been found in Pennsylvania, Rhode Island, North Carolina, Ohio, Tennessee, Virginia, Wisconsin, and Ontario.

Inoculation experiments have established the causal organism as a Nectria, closely related to *N. galligena* Bres. as delineated by Wollenweber. A similar canker has been found on butternut, but the Nectria causing this disease does not infect black walnut but does infect certain exotic species of Juglans. Neither does the Nectria from black walnut infect butternut or black oak, which is another host for a very similar Nectria canker.

Miscellaneous Disease Studies

A considerable number of attempts to isolate the organism primarily concerned with "frog-eye" leaf spot of apple resulted in obtaining a number of bacteria and fungi, among which *Sphaeropsis malorum* was most commonly found. Repeated attempts to infect leaves of young apple trees in the greenhouse resulted in failures in every case but one, in which typical small tan spots resulted from inoculation with Sphaeropsis.

Studies on internal therapy with plants have involved the use of one inorganic and three organic mercury compounds in attempts to inactivate the virus of mosaic of tobacco in the expressed juice of

diseased plants. Critical amounts which inactivated the virus were determined for uspulun, resorcin mercury, and nitro-phenol mercury, all organic compounds, as well as for inorganic mercuric chloride. Injections of organic mercury compounds into healthy plants before inoculation with mosaic virus increased the incubation period about twice that for normal plants not injected.

A high degree of variation in susceptibility to soft rot caused by *Bacillus carotovorus* and related organisms has been found among different varieties and between individuals of the same variety in a number of vegetables, notably cabbage, carrots, parsnips, and turnips. Serological and physiological studies have been instituted to aid in demonstrating the relationship between the various strains of soft-rot bacteria as well as certain organisms of the colon group.

Physiological investigations have also been continued with the genus *Phytophthora*, looking toward evolving a true species concept among the many "species" of this genus.

POULTRY HUSBANDRY

The program of Poultry Research in the past has covered a varied field, beginning about 35 years ago. At first the work was devoted largely to economic problems bearing on management of the flock and principally on feeding problems. In later years work relating more to scientific problems has been undertaken. At present the research department is devoting its tasks to three main projects. First, a continuation of the project investigating the factors affecting egg production, with the aim to determine whether the factors which determine the number of eggs laid are correlated with the fluctuations in egg weight. Second, a study of the regularity of laying within the cycle during the pullet year. It seems probable that the time intervals in laying from one egg to another within the cycles are so closely correlated with the processes of egg formation that the average length of these intervals may be used as a more convenient and shorter method of determining the potential fecundity of a laying flock. The third project is an investigation of the best temperature to use in incubating hen eggs in incubators of the cabinet type, in which the air is maintained by electric fans at a uniform temperature throughout the incubating chamber.

Factors Affecting the Weight of Hen Eggs

The sixth year was completed with 109 birds surviving out of the original 200, 21 birds having died during the year. The fifth and sixth years have shown the highest mortality rate, being 15 percent and 14 percent, respectively.

The average egg production decreased from 76 eggs in the fifth year to 59 in the sixth. This decrease, due to senescence, was 22 percent, a figure comparable with the decrease during the first three years of production.

No reduction was observed in the average egg weight as com-

pared with the former year, the weight remaining at 54.4 grams. Little change has been observed in the egg weight since the third year, at which time the maximum was reached.

From the fifth to the sixth year the total weight of eggs laid showed a decrease of 35 percent, an increased reduction of four percent as compared with the decrease between the fourth and fifth year.

Coinciding with decreased egg production was the decrease in average annual feed consumption per bird from 61 lbs. to 58 lbs.

A slight increase in average body for the flock was shown. This characteristic has deviated very little in the past three years.

Egg production apparently has no effect on mortality.

Interval as an Index of Annual Production

For estimating annual production the time interval within the cycle, even when short periods are used, has been found more reliable than winter production.

The variability in egg production has been reduced 20 percent in two years and the egg size has been materially increased, as compared with the parent stock. The rate of mortality has been unusually low. Line breeding is being used to produce a more homozygous flock of birds in respect to fecundity.

The relationship between the four months' winter production and annual production has been determined, revealing a significant positive correlation of $+.60 \pm .05$. From this value, 36 percent of the variability in annual production can be accounted for by winter production. A slightly lower value was obtained when winter production for three months was correlated with annual production. A negative correlation of $-.67 \pm .04$ between the mean time interval within the cycle for March and April and annual production accounted for 45 percent of the variability in annual production.

TABLE 6—*Weight of embryos under different frequencies of turning*

Times turned daily	Weight of embryos in grams					
	4th Day	7th Day	10th Day	13th Day	16th Day	19th Day
Turned 6 times	.0743	.8445	2.8295	7.8192	17.5373	29.8743
Turned 2 times	.0507	.7035	2.6246	7.6330	16.7288	27.7255
Difference	.0236	.1410	.2049	.1862	.8085	2.1488
Odds	0:1	262:1	525:1	2.75:1	6.24:1	17.8:1

Frequency of Turning Eggs during Hatching

This project has been reorganized to include studies on the effect of frequency of turning eggs during hatching. As shown in Table 6, a consistent difference is revealed between the average weight of nine embryos which had been turned six times daily and the average weight of nine embryos turned twice daily. However, the odds are significant for only the 7th and 10th days. These trials are being continued.

Agricultural Experiment Station Staff

JOHN R. TURNER, Ph. D., LL. D., President of the University
F. D. FROMME, Ph. D. ..... Dean and Director
GERALD JENNY, M. S., Agricultural Editor .... JOHN C. JOHNSTON, Chief Clerk

AGRONOMY AND GENETICS

R. J. Garber, Ph. D.
Agronomist and Geneticist

W. H. Pierre, Ph. D.
Associate Agronomist

M. M. Hoover, Ph. D.
Associate Agronomist

T. C. McIlvaine, Ph. D.*†
Assistant Agronomist

G. G. Pohlman, Ph. D.
Assistant Agronomist

H. K. Rowley, M. S. Agr.**
Seed Analyst

L. S. Bennett, M. S.
Graduate Assistant

A. D. Stuart, B. S.
Graduate Assistant

R. R. Robinson, B. S.
Graduate Assistant

M. H. Snyder, B. S.
Graduate Assistant

ANIMAL HUSBANDRY

E. A. Livesay, D. Sc.
Animal Husbandman

C. V. Wilson, M. S.
Assistant Animal Husbandman

J. H. Longwell, M. A.
Assistant Animal Husbandman

R. H. Tuckwiller, B. S. Agr.*
Assistant Animal Husbandman

J. H. Rietz, D. V. M.**
Associate Veterinarian

E. N. Moore, D. V. M.**
Assistant Veterinarian

J. A. Beall, M. S.
Graduate Assistant

CHEMISTRY

R. B. Dustman, Ph. D.
Agricultural Chemist

C. E. Weakley, Jr., M. A.
Assistant Chemist

T. B. Leith, M. S.**
Assistant Chemist

I. J. Duncan, B. S.
Assistant

A. H. Van Landingham, M. S.
Assistant

DAIRY HUSBANDRY

H. O. Henderson, Ph. D.
Dairy Husbandman

L. M. Thurston, Ph. D.
Associate Dairy Husbandman

G. A. Bowling, M. S.
Assistant Dairy Husbandman

R. A. Ackerman, M. S.‡
Assistant Dairy Husbandman

J. L. Barnhart, M. S.
Graduate Assistant

C. E. Teague, M. S.
Graduate Assistant

ENTOMOLOGY

L. M. Peairs, Ph. D.
Entomologist

W. E. Rumsey, B. S.**
State Entomologist

Edwin Gould, B. S. Agr.
Assistant

FARM ECONOMICS

A. J. Dadisman, Ph. D.
Farm Economist

W. W. Armentrout, Ph. D.
Associate Farm Economist

F. D. Cornell, Jr., M. S.
Assistant Farm Mechanician

R. O. Stelzer, M. S.
Assistant

HOME ECONOMICS

Rachel H. Colwell, M. A.
Home Economist

Hazel C. Cameron, M. A.
Research Specialist in Nutrition

HORTICULTURE

H. E. Knowlton, Ph. D.
Horticulturist

K. C. Westover, M. S.
Assistant Horticulturist

Leif Verner, M. S.
Assistant Horticulturist

E. N. McCubbin, M. A.
Assistant

A. P. Dye, M. S. Agr.
Assistant

W. H. Childs, M. S.
Assistant

A. L. Keller, B. S.
Graduate Assistant

PLANT PATHOLOGY

C. R. Orton, Ph. D.
Plant Pathologist

Anthony Berg, M. S.
Associate Plant Pathologist

L. H. Leonian, Ph. D.
Associate Plant Pathologist

F. J. Schneiderhan, M. S.††
Associate Plant Pathologist

A. R. Stanley, M. S.
Graduate Assistant

W. D. Henry, M. S.
Graduate Assistant

POULTRY HUSBANDRY

T. B. Clark, B. S. Agr.
Assistant

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.
**In cooperation with the State Department of Agriculture, Charleston, W. Va.
†In charge of the Lakin Experiment Farm, Lakin, W. Va.
‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.
††In charge of the University Experiment Farm, Kearneysville, W. Va.

STAFF CHANGES

New appointments to the research staff during the biennium include the following: G. A. Bowling, assistant dairy husbandman; W. H. Childs, assistant in horticulture; E. N. Moore, assistant veterinarian; G. G. Pohlman, assistant agronomist; A. H. Van Landingham, assistant in agricultural chemistry; and Leif Verner, assistant horticulturist.

Resignations during the same period include the following: Horace Atwood (retired as professor emeritus of poultry husbandry); C. H. Bruce, assistant in farm economics; R. S. Glasscock, assistant in veterinary science; L. P. Hansen, assistant agricultural chemist; M. B. Hoffman, assistant in horticulture; K. S. Morrow, assistant dairy husbandman; and L. F. Sutton, assistant dairy husbandman.

LIST OF CURRENT PROJECTS

AGRONOMY AND GENETICS

Oat investigations (CE 6)
Soybean investigations (CE 7)
Oat smut (CE 8; coop. Plant Pathology)
Cover crop experiments (CE 9; coop. Dairy Husbandry)
Pasture fertilization studies (CE 10; coop. Dairy Husb. and U. S. D. A.)
Crop rotation experiments (CE 11)
The availability of phosphorus compounds (CE 12)
Effect of soybeans on crops that follow (CE 13)
Alfalfa investigations (CE 38)
Sweet clover investigations (CE 40; coop. Agricultural Chemistry)
Crop responses to various fertilizers (CE 44; coop. Horticulture)
Breeding tobacco for resistance to root rot and high yield (P 1; coop. U. S. D. A.)
Soil acidity and plant growth (P 2; coop. Agricultural Chemistry)
Wheat investigations (H 1)
Corn investigations (H 2)

ANIMAL HUSBANDRY

Methods of finishing two-year-old steers on grass and grain (CE 14)
Forage crops and winter rations for swine (CE 15)
The control of infectious abortion (Brucella abortus infection) in cows by herd management and testing (CE 23; coop. Dairy Husbandry)
A study of the factors involved in individual vs. group feeding of growing, fattening pigs (CE 42)
Relation of round worm (Ascaris lumbricoides) infestation and vitamin-A deficiency in pigs (P 4)
Breed as a factor in sheep production and quality of products produced (P 5; coop. U. S. D. A.)
Investigations concerning treatment for stomach and lung worms in sheep and cattle (P 6)
Herd management for the production of slaughter and feeder calves (P 7; coop. U. S. D. A.)

CHEMISTRY (AGRICULTURAL)

Miscellaneous chemical investigations (CE 5)
A study of variability in composition of different skeletal parts of experimental animals (CE 20)
A study of the pigmentation and ripening of fruits (A 3)

DAIRY HUSBANDRY

The continued use of proven sires (CE 16; coop. U. S. D. A.)
A study of the different varieties of pasture for milk production (CE 18; coop. Agronomy)
Cost of raising dairy heifers in West Virginia (CE 20)
A growth study with Ayshire cattle (CE 21)
A comparative study of the microflora of raw and pasteurized grade-A milk (CE 22)
A study of the manufacture of sweet-curd, rennet-coagulated cottage cheese (CE 39)

A study of the water consumption of dairy animals (CE 41)
The effect of low-calcium and low-phosphorus rations on growing dairy heifers (P 8; coop. Agricultural Chemistry)
Constituents of milk that contribute to flavor of dairy products (P 23)
Causes for poor quality of cream transported in less than carlots (P 24)
A comparison of alfalfa and timothy hay with and without corn silage for dairy cattle (P 25)

ENTOMOLOGY

Miscellaneous entomological investigations (CE 24)
Orchard insects (CE 25)
The biology and control of the apple-infesting aphids (P 9)
The biology and control of the pistol-case bearer (P 10)
Dusts and sprays for the control of garden insects (H 3)
Relation of temperature to insect life (A 1)

FARM ECONOMICS

Deep tillage studies with field, truck, and orchard crops (CE 19; coop. Agronomy, Horticulture, and University Experiment Farm)
Practical farm building plans for West Virginia (CE 27)
Poultry as a farm enterprise (CE 28)
The status, trends, place, and outlook of the fine-wool sheep industry in the northern part of West Virginia (CE 29; coop. Extension Division)
A study of the economic and social problems and conditions of the West Virginia highland area (P 3; coop. U. S. D. A. & U. S. Dept. of Interior)
Costs, methods, and practices of marketing livestock (P 11; coop. U. S. D. A.)
A study of orchard management and of the place of orchards in the farm organization of the apple section of eastern West Virginia (P 12; coop. U. S. D. A., Pennsylvania, and Virginia)
A study of the costs, efficiency, and management of hydrant orchard spraying systems in West Virginia (P 13; coop. Plant Pathology)

HOME ECONOMICS

A study of the relation of the lipoids, particularly cholesterol, to the incidence of respiratory and middle-ear infections occurring on vitamin-A deficient diets (P 15; coop. Agricultural Chemistry)
Histology and bone growth in vitamin-deficient animals (P 26)

HORTICULTURE

Training and pruning of fruit trees (CE 30)
Potato investigations (CE 31)
Miscellaneous horticultural investigations (CE 32)
The improvement of root stocks for apple trees (P 16)
Studies on the storage qualities of fruits of the apple as affected by culture and the fertilizer treatment given the orchard (P 17)
Paper mulches vs. clean culture for vegetable crops (P 22)
Variety tests of fruit trees (H 4)
Cultural treatments and fertilizers for fruits (H 5)
Variety and strain studies of vegetables (H 8)
Sterility studies with the apple (A 2)
Hardiness studies of the fruit buds of peach (A 4; coop. Agricultural Chemistry)

PLANT PATHOLOGY

Black-walnut canker (CE 33)
Miscellaneous plant pathology investigations (CE 34)
Fruit spots of the apple (P 14)
Fusarium wilt of watermelon (P 18; coop. Agronomy and Genetics)
A study of apple "measles" (P 19)
Collor rot of apple trees (P 21)
Dusting and spraying for the control of diseases (H 7)
Apple Rust (A 5)
The effect of environment upon morphology and parasitism in fungi (A 6)

POULTRY HUSBANDRY

A study of the proper incubating temperature for eggs of the domestic fowl in incubators of the cabinet type (CE 37)
Factors affecting the weight of hen eggs (A 7)
Time factor in egg production (A 8)

PUBLICATIONS OF THE BIENNIUM, 1930-32

BULLETINS AND CIRCULARS OF THE EXPERIMENT STATION

Bul. 236. Physiological investigations on the resistance of fruit buds to freezing temperatures. H. L. Crane. Technical. 80 pp. Aug. 1930. (Out of print.)
Bul. 237. Varietal experiments with wheat, oats, barley, rye, and buckwheat. M. M. Hoover and R. J. Garber. General. 12 pp. Oct. 1930.
Bul. 238. The West Virginia community packing house at Inwood as a state service to apple growing. F. J. Schneiderhan. General. 24 pp. Nov. 1930. (Out of print.)
Bul. 239. Stationary spray systems in West Virginia. F. D. Cornell. General. 28 pages. Jan. 1931.
Bul. 240. Effects of pruning on growth and yield of cherry trees. H. L. Crane. Technical. 20 pp. Mar. 1931.
Bul. 241. Four-H clubwork in West Virginia. T. L. Harris. General. 36 pp. April, 1931.
Bul. 242. Northern and native-grown potato seedstock. K. C. Westover. Technical. 20 pp. June, 1931. (Out of print.)
Bul. 243. Soybean culture and varieties. M. M. Hoover, T. C. McIlvaine, and R. J. Garber. General. 16 pp. Sept. 1931.
Bul. 244. Report of the West Virginia Agricultural Experiment Station for the biennium ending June 30, 1930. F. D. Fromme. General. 60 pp. Nov. 1931.
Bul. 245. Seed-borne parasites—a bibliography. C. R. Orton. Technical. 48 pp. Dec. 1931.
Bul. 246. The pistol-case bearer. Edwin Gould. General. 12 pp. Dec. 1931.
Bul. 247. Pekwa—a new soybean. R. J. Garber and M. M. Hoover. General. 8 pp. Jan. 1932.
Bul. 248. The pathogenicity and the variability of *Fusarium moniliforme* from corn. L. H. Leonian. Technical. 16 pp. Mar. 1932.
Bul. 249. Efficiency of cooperative livestock shipping associations in West Virginia. W. W. Armentrout. General. 92 pp. May 1932.
Bul. 250. Varietal experiments with red clover and alfalfa, and field tests with meadow mixtures. R. J. Garber and T. E. Odland. General. 16 pp. June 1932.
Bul. 251. Finishing calves for the market as baby beeves, two-year-old, and three-year-old steers. E. A. Livesay. General. 12 pp. June 1932.
Bul. 252. The fertilization of apple orchards. III: A comparison of nitrate of soda and sulphate of ammonia. H. E. Knowlton and M. B. Hoffman. General. 12 pp. June 1932.

Cir. 56. Feeding dairy cows. H. O. Henderson and J. V. Hopkins. 20 pp. Sept. 1930.
Cir. 57. Topworking the apple tree. M. B. Hoffman. 32 pp. Nov. 1930.
Cir. 58. Save black walnut from canker. C. R. Orton and J. M. Ashcroft. 4 pp. Dec. 1930.
Cir. 59. West Virginia weeds. H. K. Rowley. 36 pp. July 1931.
Cir. 60. Instant bordeaux. F. J. Schneiderhan. 8 pp. Mar. 1932.

TECHNICAL BULLETINS PUBLISHED JOINTLY WITH THE U. S. D. A.

Tech. Bul. No. 217. Beef production and quality as affected by grade of steer and feeding of grain supplement on grass. W. H. Black, K. F. Warner, and C. V. Wilson. 44 pp. Jan. 1931.
Tech. Bul. No. 234. Marketing apples grown in the Cumberland-Shenandoah region of Pennsylvania, Virginia, and West Virginia. C. R. Swinson, J. J. Vernon, F. F. Lininger, F. P. Weaver, and A. J. Dadisman. 52 pp. Mar. 1931.
Tech. Bul. No. 303. Economic utilization of marginal lands in Nicholas and Webster counties, W. Va. Millard Peck, Bernard Frank, and P. A. Eke. 64 pp. May 1932.

No. 84. E. P. Deatrick. Computation of fertilizer mixtures from extra-high analysis fertilizers. Jour. Am. Soc. Agron. 22,8: 725-738. Aug. 1930.

No. 85. L. H. Leonian. Differential growth of Phytophthoras under the action of malachite green. Am. Jour. Bot. 17: 671-677. July 1930.

No. 86. R. B. Dustman and A. H. VanLandingham. The chemical composition of consecutive cuttings of *Andropogon virginicus* and *Danthonia spicata*. Jour. Am. Soc. Agron. 22,8: 719-724. Aug. 1930.

No. 87. L. H. Leonian. Attempt to induce mixochimaera in *Fusarium moniliforme*. Phytopath. 21,11: 895-901. Nov. 1930. (Presented at Dec. 1929 meeting of Am. Phytopath. Soc., Des Moines, Iowa.)

No. 88. R. J. Garber and M. M. Hoover. Persistence of soil differences with respect to productivity. Jour. Am. Soc. Agron. 22,10: 883-890. Oct. 1930.

No. 89. E. P. Deatrick. Solving "mixed-acid" problems by use of determinants. Jour. Ind. and Eng. Chem. 23: 34. Jan. 1931.

No. 90. T. B. Clark. The relationship between annual egg production and mean egg weight in White Leghorn fowls. Poult. Sci., Proc. 1930 meeting.

No. 91. H. E. Knowlton and M. B. Hoffman. Nitrogen fertilization and the keeping quality of apples. Am. Soc. Hort. Sci., 1930 Proc. Presented at the annual meeting of the Society at Cleveland, O., Dec. 1930.

No. 92. K. C. Westover. The effect of green sprouting potato seed tubers on earliness and yield. Potato Assoc. of Am., Proc. 1930: 12-13. Dec. 1930. Presented at the annual meeting of the Potato Association of America at Cleveland, O., Dec. 1930.

No. 93. R. B. Dustman and L. C. Shriver. The chemical composition of *Ambrosia trifida* at successive growth stages. Jour. Am. Soc. Agron. 23,3: 190-194. Mar. 1930.

No. 94. H. K. Rowley. When to treat quackgrass most effectively with chlorates. Jour. Am. Soc. Agron. 23, 1: 41-42. Jan. 1931.

No. 95. R. J. Garber, T. C. McIlvaine, and M. M. Hoover. A method of laying out experiment plats. Jour. Am. Soc. Agron. 23,4: 286-298. April 1931. Presented at Nov. 1930 meeting of the Society at Washington, D. C.

No. 96. R. J. Garber. Inbreeding with particular reference to maize. Jour. Amer. Soc. Agron. 23,7: 534-548. July 1931.

No. 97. Anthony Berg. The causative organism of a papular type of apple measles. Sci. n.s. 74, 1924: 485-486. Nov. 13, 1931.

No. 98. L. H. Leonian. Heterothallism in Phytophthora. Phytopath. 21, 10: 941-955. Oct. 1931.

No. 99. J. M. Ashcroft. Black-walnut canker caused by a Nectria. Phytopath. 22, 3: 268-269. Mar. 1932. Presented at annual meeting of the Am. Phytopath. Soc. at New Orleans, La., Dec. 1931.

No. 100. R. J. Garber. The relative yield of a first-generation cross between two varieties of corn before and after selection. Jour. Am. Soc. Agron. 23, 8: 647-651. Aug. 1931.

No. 101. H. O. Henderson, K. S. Morrow, and R. B. Dustman. Changes in the chemical composition of mangels and rutabagas during storage. Jour. Agr. Res. 43, 10: 919-930. Nov. 15, 1931.

No. 102. W. H. Pierre. The effect of nitrogenous fertilizers on soil acidity. Jour. Ind. and Eng. Chem. 23: 1440. Dec. 1931. Presented at the Sept. 1931 meeting of the Amer. Chem. Soc. at Buffalo, N. Y.

No. 103. L. H. Leonian. The effect of position of the inoculum upon growth of some Trichophytons in the presence of dyes. Arch. Dermatology and Syphilology. 25: 1016-1020. June 1932.

No. 108. H. E. Knowlton. Pollination studies with some newer apple varieties. Am. Soc. Hort. Sci. 28: 71-73. Proc. 1931. Presented by title at the annual meeting of the Society at New Orleans, La., in Dec. 1931.

No. 109. Leif Verner. Notes on the 1930 drought in West Virginia orchards. Am. Soc. Hort. Sci. 28: 646-653. Proc. 1931. Presented by title at the annual meeting of the Society at New Orleans, La., in Dec. 1931.

CIRCULAR 54 MARCH, 1929

ORCHARD SPRAYING *in* West Virginia

BY E. C. SHERWOOD
AND L. M. PEAIRS

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, DIRECTOR

Greater Orchard Profits

Depend on

Producing fruit of *high quality,* which insures success in marketing at the highest prices obtainable.

Increasing yields, thus reducing production cost.

Spraying Properly—as a means of obtaining *quality fruit* and *maximum yields.*

Spraying to be Effective

Must be

Timely—as in many cases even a day or two too early or late may mean failure.

Thorough—for unless every part of the tree affected by the disease or insect pest is adequately covered the control will be only partial.

With *proper materials* that have been tested and proved to be satisfactory.

Adapted to meet changing conditions and seasonal requirements.

Based on knowledge gained through scientific research studies and practical experience.

Orchard Spraying in West Virginia

ORCHARDISTS who attempt to grow fruit that will meet the exacting marketing requirements of today are confronted with many problems. The most successful growers are those who avail themselves of the best sources of information about their business. They have learned to recognize the value of scientific investigation of orchard problems and to apply the results as far as possible to their own conditions. One very important problem is the production of the maximum quantity of clean fruit, computed on the basis of the individual tree. It is a recognized fact that this can not be accomplished unless the trees are properly sprayed.

There are two general types of injury to fruit which are preventable by spraying. These are insect injury and injury by the various fungous diseases. The progressive fruit grower realizes that the protection of his fruit from these troubles is a problem which is constantly changing and that he must adapt his orchard practices to meet changed conditions. It is to supply the consequent demand for information that this summary of the latest recommendations is published. In this circular the troubles common in West Virginia and the means for their prevention are discussed in some detail, and then the control methods are summarized in the form of spray schedules.

The spray schedules contained in this circular are basically the same as those recommended by the states of Virginia, Maryland, Pennsylvania, and Ohio, although a few minor changes have been found necessary on account of local conditions. The apple spray program in particular was compiled in cooperation with representatives from these states, who have met at appointed times to correlate recommendations and work out a joint schedule which should be applicable to the entire region.

THE WEST VIRGINIA SPRAY SERVICE

It is impossible to formulate a spray schedule in advance of the season that will meet the demands of every situation in this or any other state. Such schedules are intended primarily to furnish the growers with a brief summary of spray recommendations to serve as a guide to the season's operations, the details of which must necessarily vary according to seasonal conditions. They also give advance information as to the materials needed so proper preparation can be made.

With this in view, a schedule of applications is arranged, based primarily upon the stage of development of the trees. The exact time

to apply sprays to be most effective, however, depends more upon the stage of development of the insects and the fungi which cause disease than upon that of the trees. While the development of the pests parallels quite closely that of the trees, the former is seemingly more subject to variations due to seasonal conditions. Hence, the time specified in a spray program arranged in advance of the season can be only approximate.

The determination of the exact time when sprays will be most effective for control of diseases and insects involves a somewhat technical study of their seasonal development, for which the average grower is not equipped. For the purpose of assisting the orchardist in correctly timing the sprays to obtain the best results the West Virginia Orchard Spray Service has been established. This service is disseminated by the Extension Division of the College of Agriculture and is governed by information furnished by the Experiment Station. Every fruit grower may receive this service free of charge. Application for the Spray Service should be made to the Extension Division at Morgantown.

ORCHARD INSECTS

San Jose and Other Scales

The San Jose scale is the common scale of apple and peach orchards and is the one which attracts most attention. It attacks the fruit and causes bright-red discolorations, usually about the stem. It lives on the twigs also and in advanced cases may cause severe twig injury and even the death of the tree. Usually, on the apple, the damage is noticed only on the fruit. Other common scales of the apple are the much larger forms called scurfy-scale and oyster-shell scale. The former is white in color and the latter dark brown. Treatment is ordinarily the same for all scale insects on the apple. The dormant spray of lime-sulphur, miscible oil, or lubricating-oil emulsion or the delayed-dormant spray with the same materials repeated each year will control all these scales. Thorough spraying, especially in the tops of the trees, is essential.

Peach Lecanium or Terrapin Scale

The peach lecanium is a much larger scale than the San Jose. It is about one-eighth of an inch in length and nearly hemispherical in shape. It is established in peach orchards in some parts of the state. A delayed-dormant spray with miscible oil or with lubricating-oil emulsion is the only treatment which has given satisfactory results for this insect. Lime-sulphur is not effective for this scale.

Apple Aphids

There are several forms of aphids or plant lice found on the apple. Of these only the green apple-aphis and the rosy aphis are dangerous. Both kinds cause injury to fruit and foliage, but injury from the rosy aphis is liable to be more severe than that from the green aphis. The

latter may cause late season foliage injury. Treatment varies somewhat. The delayed-dormant spray with lime-sulphur combined with nicotine, if properly applied, gives good results. When conditions are such that thorough spraying is impossible, enough aphids may survive the first treatment to cause injury. In such cases, emergency treatments with nicotine should be applied at the time of the cluster-bud spray. Other materials used for aphis control have not yet given results as uniform as those obtained with nicotine. (See Derrisol, page 14; Oil Sprays, page 19; Concentrated Lime Sulphur, page 14; and Delayed-Dormant Spray, page 23.) Summer applications of nicotine may be necessary to prevent late injury by the green aphis.

Apple Red-Bugs

Apple red-bugs are sucking insects which injure the fruit of the apple. They puncture the skin and cause deep pits in the sides of the fruits resulting in reduced size and serious malformations. The red-bugs are present in the young stages at the time of the cluster-bud spray, but are more abundant at the time of the petal-fall application. If they are known to be present the trees should be treated with nicotine applied in the petal-fall spray, and care should be taken to have this spray applied in quantity to the under sides of the leaves.

Leafhoppers

Two kinds of leafhoppers may be found on the apple, and there is some difference both in the season and in the nature of their injury. The apple leafhopper curls the leaves early in the summer, while the other form, called the rose leafhopper, merely causes the leaves to turn brown and dry during late summer. The latter form has been most injurious in the fruit regions. Thorough drenching with the summer strength lime-sulphur applied in the two-weeks spray will kill many of the young leafhoppers and usually prevents most of the late injury. Since Bordeaux mixture is a repellant for these insects on other plants, it is possible that this material may afford some protection when applied in summer sprays.

Canker-Worms

These well known early spring measuring worms are sometimes serious pests, defoliating the trees before the blooming period. The arsenate of lead in the cluster-bud spray controls them without difficulty. It must be applied promptly at first sign of injury.

The Bud-Moth

The injurious stage of this insect is a small caterpillar which feeds on the opening buds of the apple, sometimes eating down into the buds before they begin to unfold. Fortunately, the insects are seldom numerous in the fruit-growing sections of the state. The arsenate of lead at the cluster-bud stage will usually be found to afford sufficient protection, but in some cases it has been found necessary to add arsenate of lead to the delayed-dormant spray mixture.

The Curculio

A curculio, usually called the plum curculio, attacks apples, pears, plums, peaches, and cherries. It is the only important cause of wormy plums and cherries. While it does not cause wormy apples, it produces knotty and misshapen fruits which are just as unsalable as wormy ones. Its injury in West Virginia is comparatively moderate in extent. The adult, which is a beetle, feeds on the foliage from early spring for a period of several weeks. Keeping the foliage covered with arsenate of lead as much of the time during this period as possible will control the insect by killing the beetles before they lay their eggs which are deposited in the fruits after they have reached some size. This treatment applies to all fruits attacked by curculio.

The Pistol Case-Bearer

The pistol case-bearer is a native insect which has long been present in orchards in West Virginia, but has not caused material damage until recently when it has developed into a very serious pest in some orchards. For such conditions, the methods of control recommended elsewhere in cases of rather light infestation have not proved satisfactory. Probably the most benefit can be obtained by the addition of about four pounds of arsenate of lead to 100 gallons in the delayed-dormant spray, and the increase of the arsenate in later sprays to this quantity. It is possible that extra strength nicotine will also be of value, but experimental work has not progressed far enough so that definite recommendations can be made.

Mites

Mites attacking the apple are of several species. The most important of these is the European red-mite which has not yet become established in West Virginia in sufficient numbers to be injurious. Since it is injurious in adjoining states, however, it may be expected to increase in West Virginia. The native species rarely require special treatment. Should the European red-mite develop in injurious numbers, an oil spray must be used at the delayed-dormant period for its control.

The Codling Moth

Codling moth is the only insect which to an important extent causes wormy apples. The nature of its injury is universally known to growers. There are always two broods in West Virginia and practically always a more or less complete third brood occurs. For some time the method followed for control of this insect was to depend mainly upon the petal-fall spray to prevent injury by the first brood, then to apply a mid-season spray to destroy the second-brood worms.

Since due consideration must now be given to the arsenical residue situation, late summer sprays containing arsenate of lead are not to be recommended, especially for commercial growers. Instead, every effort should be made to eliminate the first brood of codling

moth from the orchard by means of earlier sprays, thus making a second-brood spray less necessary. To accomplish this, three cover sprays after the petal-fall application are generally required in most orchards. The first should be timed to cover the trees at the beginning of the period through which the eggs of the first brood will be hatching, usually about three weeks after petal-fall; the second, just before the eggs are hatching in greatest numbers (peak of the hatch), about five weeks after petal-fall; and the third, about two weeks later, to continue protection through the later part of the hatching period.

Apple Leaf Roller

The apple leaf roller feeds on the foliage and, later in the season, on the fruit. It eats the surface of the apple, skin and all, and thus may be distinguished from the codling moth and the lesser apple-worm. It frequently forms a web over the surface where it feeds. The schedule of sprays recommended for control of the codling moth has afforded adequate protection against the leaf roller in most orchards. There is some indication, however, that this insect is increasing in numbers and destructiveness in West Virginia; consequently, the treatment recommended may require revision.

Lesser Apple-Worm

Injury from this insect resembles that by codling moth, but the lesser apple-worm works just beneath the skin of the apple while the codling moth almost always makes its way directly to the core. The codling-moth spray schedule should control the lesser apple-worm which has not yet become a very serious factor in apple growing.

Miscellaneous Caterpillars

The tent-caterpillar and the bagworm in the spring, and the yellow-necked apple-caterpillar and the fall webworm in the late summer are all capable of injuring the apple crop. Several other less common leaf-eating caterpillars may do the same. All these are controlled when the usual schedule of sprays for the more important insects is followed.

Oriental Fruit Moth

The oriental fruit moth is an imported insect which has become established throughout the state within recent years. Peaches suffer most from its attack, but it may do some injury to apples and other fruits as well. It is closely related to the codling moth and the late broods bore into the fruit in a manner similar to that of the codling moth. Larvae of earlier broods work largely in the twigs.

Intensive studies by the United States Department of Agriculture and various Experiment Stations have failed so far to develop a system of treatment which will control the insect. Thorough spring cultivation under the trees and as close to the trunks as possible is said to reduce the damage. The paradichlorobenzene applied for the peach tree borer is said also to kill some of the fruit-moth pupae.

Nicotine added to the sprays in the regular spray schedule also reduces the number of larvae in twigs and fruit, but it is doubtful whether it is worth what it costs for this purpose. Bait pans to attract the moths are extensively used, but their use is a control measure of little value. Ultimate control will probably result through the development of parasites which seem to reduce the numbers of the fruit moth after it has been established for a few years.

The Cherry Leaf-Beetle

The cherry leaf-beetle is a small red insect, much like the common cucumber beetle in size and shape. It sometimes riddles the leaves of the plum and cherry and destroys the foliage. This insect is very irregular in its occurrence and therefore need not be sprayed for every year. At the first sign of an unusual number being present, however, the foliage should be covered with arsenate of lead at about double the usual strength; that is, from two to three pounds of the powder to fifty gallons of water.

Cherry and Plum Aphids

Several species of aphids or plant lice attack both the plum and the cherry. They are irregular in the time of appearance and vary in abundance. At the first sign of injury the nicotine spray should be applied as for apple aphids. It will not do to delay this spray until the foliage has been curled enough to prevent the spray from wetting the aphids.

Rose-Bugs or Rose-Chafers

These beetles, usually most injurious to the grape, sometimes injure fruit trees, especially the cherry. The only treatment known is to spray with arsenate of lead, two to three pounds to fifty gallons of water, with some cheap syrup added as a bait. About a gallon of syrup, such as is sold for stock feed, to a barrel of spray may be used.

ORCHARD DISEASES

Apple Scab

Apple scab has become very prevalent in West Virginia and ranks first in importance among the apple diseases. The Rome, Winesaps, Ben Davis, Gano, and Delicious are among the more susceptible varieties. Grimes, York Imperial, and Yellow Transparent are much less so, but no variety is immune.

The apple scab fungus lives over winter in old diseased leaves. In these are produced the winter spores which begin to mature about the time the blossom clusters are opening. During the first rainy period after they have matured, these spores are forcibly discharged from the leaves and, being extremely light, are carried by air currents to the developing buds. Infection takes place, and in

about two weeks the fungus begins to produce great numbers of summer spores. From these, secondary infections take place and successive crops of spores are produced throughout the summer.

The first spray to control scab must precede the first winter spore discharge. To make certain of this, spraying should begin just as soon as the buds in the blossom clusters have separated. If rain falls after this application, it should be repeated on the most susceptible varieties before the blossoms open. Since winter spores will continue to be discharged after each rain for about a month, additional sprays are necessary at petal-fall and from two to three weeks later.

The importance of preventing primary infections during the cluster-bud period can not be over-emphasized. Both the fruit and the leaves are highly susceptible at this stage, and the affected apples are usually deformed. Since the fungus grows under the outer covering of the leaves and fruit, it can not be destroyed by any subsequent spraying; hence, there is constant danger throughout the season from summer spores.

The summer strength lime-sulphur solution is effective in controlling scab, if properly applied. Bordeaux mixture is highly effective also, but is not always safe to use for the cluster-bud or petal-fall sprays. Varieties like Ben Davis, Baldwin, Jonathan, Northwestern, Rambo, Smith Cider, Wealthy, Winesap, and Yellow Transparent are frequently so severely russeted by early Bordeaux sprays that the resulting damage to the fruit is greater than that which might have been caused by the scab.

Bitter-Rot

On some varieties of apples, in certain localities, serious trouble is often caused by bitter-rot. It is most prevalent in hot wet weather and usually develops rather late in the season. The disease often appears suddenly, and spreads rapidly under favorable weather conditions. When once started it is very difficult to stop; hence, it is important that the first spray be applied before infection is expected to take place. Bordeaux mixture must be used, and the first application should be made about the first of July. Three more applications at intervals of ten days to two weeks are necessary for complete protection.

Black-Rot

Black-rot of the fruit is produced by the same fungus which causes the leaf-spot or "frog-eye." While this organism sometimes succeeds in gaining entrance into the apple through the undamaged skin, it oftener follows some injury, usually due to insect punctures. Control of black-rot of the fruit, therefore, is based largely upon the prevention of such insect injuries as are described under the discussions of the various insects. The leaf-spot form of the disease

is usually controlled by the scab sprays, but when injury has been serious, additional sprays may be necessary for complete control.

The black-rot fungus winters in cankers on twigs and limbs. These cankers are very generally produced on twigs injured by fire blight. Spraying to prevent fruit-rot and leaf-spot cannot be fully effective unless all cankered and dead material is removed from the trees and destroyed before early spring.

Apple Blotch

This trouble is serious in the northern part of the state on Northwestern, Duchess, Smith Cider, Stark, and the Pippins. In the southern part of the state it also becomes serious on Rome, Ben Davis, and a few other less important varieties. It is essential that the difference between blotch and scab be recognized, since the control measures are different. The spores of the blotch fungus are formed in over-wintering cankers on the twigs. These spores do not become mature until from about two to six weeks after petal-fall. During damp weather they ooze out onto the surface of the cankers and are carried by wind, water, and insects to the fruit and to other twigs where infection takes place.

Lime-sulphur has not proved satisfactory for control of blotch; consequently, Bordeaux mixture should be used. The first application must be made within two weeks after petal-fall. Two more applications at intervals of about two weeks are essential and, if the season is unusually rainy, a fourth spray may be necessary. Sprays should be applied in advance of rainy periods when possible.

Sooty Blotch and Flyspeck

Sooty blotch, also called sooty smudge and "cloud," produces a cloudy or smoky appearance of apples and pears. Accompanying sooty blotch there may be a disease evidenced by small black dots resembling to a remarkable degree ordinary flyspecks. The damage done by these diseases is not extensive, since the growth is entirely superficial, but the market value of the fruit may be very materially reduced. The troubles usually appear late in the season and only during wet summers, except occasionally in orchards on low ground. In some such orchards which have not been properly pruned sooty blotch and flyspeck have often been the cause of more culls than all the other troubles combined. Control consists primarily in opening the trees by careful pruning so as to allow free circulation of air. This may be all the special treatment that is necessary. During wet summers, however, it is advisable to apply sprays about the middle of July and the first of August in addition to following the regular spray program.

Phoma Spot

Phoma spot, also called New England fruit spot and Brooks' spot, has not been very troublesome in West Virginia, but occa-

sionally causes serious loss when conditions are suited to its development. This disease should not be confused with the trouble variously known as Baldwin-spot, Stippen, or bitter pit; nor with Jonathan-spot—a spot rather similar in appearance to Phoma, which is frequently quite common on Jonathan. Bitter pit and Jonathan-spot are not fungous diseases and cannot be controlled by spraying.

Fruit infection apparently does not occur until mid-season. Due to the relatively long incubation period of the disease, spots are generally not observed until late in the season, sometimes not until picking time. They may still be so inconspicuous at this time as to escape notice and are not observed until after apples are placed in storage. The three-weeks spray is probably the first application that is effective in preventing infection. To provide complete protection, this should be followed by two more sprays at intervals of about two weeks.

Powdery Mildew of Apples

Powdery mildew is generally the first disease to make its appearance in the spring. The twigs, leaves, and floral parts are dwarfed and deformed and the set of fruit may be greatly reduced. The disease occasionally become serious on several varieties, although Jonathan seems to be the most susceptible of the important varieties. The lime-sulphur sprays applied for apple scab will control this disease.

Spongy Dry-Rot

Spongy dry-rot, also called Volutella rot, caused material damage in West Virginia for the first time in 1923. It was observed only on Northwestern, but other varieties, especially in the southern part of the state, may be affected. This trouble resembles bitter-rot, but is distinguishable by the coal-black color of the spot. No experiments on control of this disease have been made, but probably the regular apple-blotch sprays will control it.

Brown-Rot

Brown-rot is the most important fruit disease of the peach, plum, and cherry. In dry years it does not cause material damage, but in wet seasons it may destroy the greater part of the crop. A sound fruit, especially when nearing maturity, may be infected by the brown-rot fungus, but it much more readily attacks one with a break in the skin, due in most cases to insect injury. Particular care must be taken to control the plum curculio, since this insect is responsible for most skin punctures. Sprays for insect control are then supplemented by the application of self-boiled lime and sulphur or dry-mix on peaches, and of commercial lime-sulphur on plums and cherries. These later sprays should, when possible, be

applied in advance of rainy periods. The number of applications will depend on the season and on the lateness of the variety.

Peach Scab

Peach scab is very prevalent in West Virginia. While scab does not cause decay, the market value of infected fruit is lowered on account of the unsightly spotting. The spots may become so numerous as to cause large irregular areas, and severe cracking of the fruit may result. Frequently the peaches are much deformed. The disease is controlled by the treatment applied for brown-rot.

Peach Leaf Curl

In unsprayed orchards, leaf curl is one of the most destructive diseases of the peach. Since it does not become injurious every year, however, growers are apt to neglect the orchard until the disease is evident. It is too late then to remedy the trouble. This is poor policy on the part of the peach grower who wishes to continue in the business, since the injury to the current year's growth affects not only the growing crop, but may cause a very material reduction in the crop the following year.

Control of peach leaf curl is a very simple process. A single application of any good fungicide, either in the fall or early in the spring before the buds open, will prevent the disease. The dormant spray of lime-sulphur is ordinarily recommended for control of both scale and leaf curl. If no scale is present, the treatment may be made less expensive by applying a 1 to 15 lime-sulphur spray, but in any case it *must* be applied before the bud scales begin to separate.

COMMON INSECTICIDES AND FUNGICIDES

Most sprays applied to orchard trees are composed of a combination of an insecticide, or insect killing material, and some fungicide, or material intended to prevent disease infection. In a few cases one material serves both purposes. A list of the spray materials most commonly used and recommended, together with some discussion of their properties and preparation follows.

Arsenate of Lead

Arsenate of lead is the poison most commonly used to kill chewing insects, such as codling moth, leaf roller, and curculio. The commercial product comes in two forms, paste and powder. Of late years the powder has almost entirely displaced the paste. The national insecticide law requires lead arsenate to conform to certain standards of strength and purity, so from this standpoint there is little choice among the different brands. Some brands may be superior, however, on account of their physical properties. A very light, fluffy powder is generally to be preferred, since it stays in

suspension better and is likely to give a more even coating of the foliage.

Dilution *(Very Important):* For all spraying operations, unless otherwise specified, the powdered lead arsenate should be used at the rate of 3 pounds to 100 gallons of liquid, and the paste at double this amount. Strengths indicated elsewhere in this circular are based on the arsenate in powdered form. It is very important to follow the correct method of mixing arsenate of lead with lime-sulphur, or else certain chemical reactions will occur which result in the formation of a black sediment with the liberation of free arsenic. This water soluble arsenic is probably the cause of most of the spray burn usually attributed by growers to the lime-sulphur.

Lead arsenate and lime-sulphur should be combined as follows: For every pound of the arsenate add 2 pounds of slaked stone lime or 3 pounds of hydrated lime. These materials should first be thoroughly mixed in water and then poured into the tank of lime-sulphur. For convenience, after carefully slaking the stone lime, it should be mixed with water at the rate of 1 pound of lime per gallon of water. A gallon of this mixture when well stirred represents 1 pound of lime. The same procedure may be followed with the hydrated lime, or the required amounts of this lime and the arsenate may be mixed in any convenient quantity of water to make a paste thin enough to pass readily through the tank strainer.

Although the addition of lime to lime-sulphur-arsenate mixtures to prevent spray burn has been quite generally recommended, this material has several objectionable features. Consequently, considerable experimental work has been done to determine a more satisfactory method, and the whole subject of the causes and prevention of spray injury is still under investigation. The Michigan Agricultural Experment Station has recently reported results from the use of iron sulphate for this purpose which indicate that this material is more satisfactory than lime. The method recommended is as follows:

A stock solution is made by dissolving the iron sulphate at the rate of one pound to one gallon of water. To make 100 gallons of spray, the tank is filled about three-fourths full of water and 1¼ gallons of this stock solution added while the agitator is running. Then, 3 pounds of arsenate of lead which has been mixed into a thin paste with water is added. Next, the required quantity of lime-sulphur concentrate is added, and the process completed by filling the tank with water. The resulting mixture will be almost black, but it is said to turn to a rust color in a few days after it is applied to the trees.

Nicotine

Nicotine is the most effective contact insecticide known for such sucking insects as aphids and red bugs. The commercial product containing 40 percent nicotine sulphate is sold under various

trade names, such as "Black Leaf 40", "Hall's Nicotine", etc. It is not advisable to try to prepare homemade nicotine extract for a commercial orchard.

Dilution: Use 1 pint of nicotine sulphate to every 100 gallons of spray mixture.

Derrisol

This is a new contact insecticide which is prepared from extracts of the Derris plant found in the East Indies. It shows considerable promise of becoming a reliable substitute for nicotine sulphate, since some very effective results against aphids and certain other sucking insects have been obtained. If further experiments verify these results, the use of Derrisol may mean a material saving to the grower.

Concentrated Lime-Sulphur

Lime-sulphur is one of the most useful of spray materials, serving both as an insecticide and as a fungicide. It is made and kept in concentrated form and diluted with water to make the strength of spray proper for winter or summer spraying. At winter strength, lime-sulphur is used as a contact insecticide to destroy scale insects, and as a fungicide. For summer spraying, it is used in a much more dilute form and is of value principally as a fungicide. Lime-sulphur will not control bitter-rot of apples, however, and is not generally considered to be as effective as Bordeaux for preventing apple blotch. It should never be used on peaches during the growing season.

Many commercial brands of concentrated lime-sulphur which are satisfactory and reasonably cheap are on the market. Those who use large quantities, however, may find it to their advantage to make their own concentrate. Anyone interested in the construction and operation of lime-sulphur plants is referred for information to Farmers' Bulletin No. 1285, which may be obtained on application to the United States Department of Agriculture, Washington, D. C.

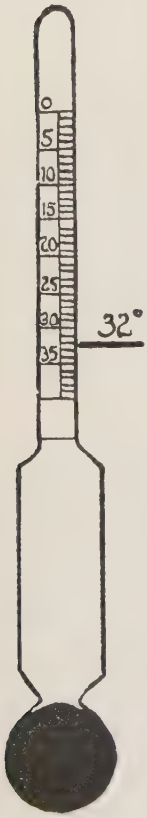
Preparation: The formula in most general use for making lime-sulphur concentrate in moderate quantities at home requires 50 pounds of good stone lime, 100 pounds of sulphur, to 50 gallons of water. Hydrated lime may be substituted for the lump lime, but the amount used must be one-third more by weight. The concentrate may be cooked in a large iron kettle over a fire, or in a barrel or tank by steam.

To make 50 gallons of concentrate, slake the lime with 15 or 20 gallons of water in the container in which the cooking is to be done. Add the sulphur gradually to the slaking lime, stirring well to prevent the formation of lumps. (The sulphur should be mixed with a quantity of water sufficient to make a thin paste before it is added to the lime.) Now, increase the contents of the container,

by adding water, to 50 gallons and boil until the sulphur is all dissolved. This usually requires from 40 minutes to an hour of continuous boiling. During the process, *stir constantly*, and *keep the contents up to 50 gallons* by adding water, if necessary, to replace that lost by evaporation. A mark on the container, or a notch on a stick, will serve to show the depth required to make 50 gallons.

Strain the solution through a brass strainer as it is poured into barrels or a reservoir for storage. The concentrate will keep without any change in composition if stored in filled and tightly-closed barrels. It may be kept in open vessels by adding enough oil to form a layer over the surface to prevent the access of air. Freezing does not alter the composition of the concentrate.

TESTING: Experience in preparing concentrated lime-sulphur shows that the product will vary in specific gravity, due principally to variation in the quantity and quality of the lime used, and to the length of the boiling period. It is necessary to know the specific gravity of *every lot* of concentrate in order to determine the quantity to be used for the spray mixtures. By using a Baume hydrometer, the test can easily be made and the figures recorded on the container. The hydrometer is an instrument which floats in the liquid and the test is indicated by the figure which shows at the surface of the liquid on the stem of the instrument. This Baume test is simply an indication of the weight of the concentrate compared to water. The specific gravity hydrometer may be substituted for the Baume.



Baume Hydrometer

The standard strength of concentrated lime-sulphur has a specific gravity of 1.283 which corresponds to a Baume reading of 32. The formula given in this circular is calculated to produce concentrate of standard strength, but in actual practice it may vary considerably as previously explained. When the concentrate is above or below the standard, it is necessary to vary the quantity used to make the spray mixture, because the spray applied to the trees *must always be uniform*. If too strong, it may injure the trees; if too weak, it will not be effective. When diluted for winter spraying, the mixture should test practically 5 degrees Baume, while the summer strength spray mixture should test 1.25 degrees.

One method of insuring uniformity in strength of the diluted spray mixtures is to test in the tank with the hydrometer. Most growers will probably find it more convenient, however, to make dilutions according to Table 1 which shows the quantity of concentrate, varying in Baume test from 23 to 35 degrees, to be used for winter and summer spray mixtures.

TABLE 1.—Proper Dilution for Lime-Sulphur of Different Baume Readings for Winter and Summer Spraying.

Specific Gravity	Baume Test in Degrees	Rate of Dilution		Quantity for 100 Gallon Tank	
		Winter Spraying	Summer Spraying	Winter Spraying	Summer Spraying
1.318	35	1 to 9	1 to 45	11 gallons	9 quarts
1.306	34	1 to 8¾	1 to 43¼	11½ gallons	9½ quarts
1.295	33	1 to 8¼	1 to 41½	12 gallons	10 quarts
1.283	32	1 to 8	1 to 40	12½ gallons	10 quarts
1.272	31	1 to 7½	1 to 37¾	13½ gallons	10½ quarts
1.261	30	1 to 7¼	1 to 35¼	14 gallons	11 quarts
1.250	29	1 to 6¾	1 to 34¼	15 gallons	11½ quarts
1.239	28	1 to 6½	1 to 32¾	15½ gallons	12 quarts
1.229	27	1 to 6	1 to 31	16½ gallons	12½ quarts
1.218	26	1 to 5¾	1 to 29½	17½ gallons	13½ quarts
1.208	25	1 to 5¼	1 to 27¾	19 gallons	14½ quarts
1.198	24	1 to 5	1 to 26	20 gallons	15½ quarts
1.188	23	1 to 4½	1 to 24¼	22 gallons	16½ quarts

Dry Lime-Sulphur

Lime-sulphur in powdered form has been on the market for several years and has been found to be an acceptable substitute for the liquid. It is a very convenient form to use when only a small quantity of spray is required, but it is rather too expensive for spraying large orchards. For dormant spraying it should be used at the rate of 30 pounds to 100 gallons of water, and for summer spraying, 6 pounds to 100 gallons. This material should never be used for spraying peaches during the growing season.

Self-Boiled Lime and Sulphur

Ordinary concentrated lime-sulphur, even at greatly reduced summer strengths, cannot be applied with safety to the foliage of peach trees. For this reason, self-boiled lime and sulphur is the fungicide which has been substituted for spraying peaches during the growing season. Since this material cannot be stored, it must always be freshly prepared when needed.

Preparation: Use a good grade of stone lime free from air-slaked particles. Place 8 pounds of the lime in a vessel and start slaking. It is sometimes advantageous to use hot water, particularly with a slow-slaking lime. As soon as slaking begins, add 8 pounds of sulphur which has been made up into a thin paste with water. Stir vigorously and add water as required to prevent burning. Cool the mixture immediately by adding water just as soon as slaking ceases which may be in from 5 to 30 minutes, depending upon the quality and condition of the lime.

Dilution: The product resulting from this formula should be strained into the sprayer tank and diluted to 50 gallons for spraying.

By using 32 pounds of lime and 32 pounds of sulphur, enough of the mixture may be made at one time for 200 gallons of spray.

Dry-Mix Sulphur Lime

Dry-mix is a recently developed spray material which is rapidly replacing self-boiled lime and sulphur as a summer spray for peaches. It has several advantages over the self-boiled material. It has better sticking qualities, gives better control of diseases, and is cheaper and easier to prepare at home. If kept in a dry place, the dry-mix does not deteriorate, so a supply may be prepared in advance of the spraying season and used as needed. It may become lumpy, however, if stored for some time, and should be sifted before it is placed in the spray tank to remove lumps which clog the pump strainers.

Since the formula for making dry-mix has become standardized, many commercial brands which are satisfactory and reasonably cheap have appeared on the market. Many people prefer to buy these products which are ready to be added to water for spraying. For the benefit of those who wish to make their own dry-mix the following directions for its preparation are given.

Preparation: Dry-mix is prepared according to a standardized formula which requires 64 percent of sulphur, 32 percent of hydrated lime, and 4 percent of calcium caseinate. The latter is sold under various trade names, such as Kayso, Spreado, etc. The sulphur used must be a *finely powdered dusting sulphur,* since the ordinary forms of powdered sulphur are too coarse to make an effective spray mixture. For making a small quantity of dry-mix the following formula is convenient:

8 pounds of dusting sulphur
4 pounds of hydrated lime
½ pound of calcium caseinate (Kayso)

The same formula figured on the basis of 100 pounds of sulphur for making larger quantities of dry-mix is as follows:

100 pounds of dusting sulphur
50 pounds of hydrated lime
6¼ pounds of calcium caseinate

It is essential that these ingredients be *mixed very thoroughly.* With sufficient care this can be done in a box with a shovel or a hoe, but it is much more easily and rapidly done by using some form of mechanical mixer. Regular dust mixers, concrete mixers, barrel churns, or other devices of this type have been used satisfactorily. A home-made mixer can be made by mounting a barrel so that it can be revolved with a crank. Seven or eight smooth stones about the size of an apple placed in the barrel with the ingredients act as mixers as the barrel is revolved.

Dilution: The dry-mix should be mixed with water at the rate of 8 pounds for every 50 gallons, or 32 pounds for a 200 gallon tank.

The material should first be sifted to remove any lumps. Place

the quantity required for the tank of spray in a barrel or other convenient vessel and add water to make a thick doughy paste after stirring with a paddle. More water is then added and this mass is worked up into a thin paste that can be poured through the tank strainer. While the agitator is running, this paste is poured into the spray tank about half full of water, after which the tank is filled.

Caution *(Important)*: To prevent burning when arsenate of lead is used with dry-mix, add 3 pounds of slaked stone lime, or 4 pounds of hydrated lime for each pound of the arsenate. The lime and the arsenate should first be mixed into a thin paste with water and this added to the diluted dry-mix while the agitator is running.

Bordeaux Mixture

Bordeaux mixture is the most effective fungicide known for the control of many diseases, particularly apple blotch and bitter-rot. It is commonly used only as a mid-season spray for apples. At this time it is much safer to use than lime-sulphur. If used early in the season, however, russeting or burning of the fruit is liable to follow, particularly on certain varieties. Bordeaux should never be used on peaches during the growing season. Its only value in insect control lies in the fact that it acts as a repellant to certain beetles and leafhoppers.

Preparation: Bordeaux mixture will not keep, so must be freshly prepared each time it is used according to the following formula:

Copper sulphate (bluestone)	**2 pounds**
Stone lime (quick lime)	**4 pounds**
Water	**50 gallons**

There are several good methods for making Bordeaux, the essential feature of each being that concentrated solutions of the bluestone and the lime must never be directly mixed together. The following procedure for making 50 gallons of Bordeaux should be convenient:

Dissolve 2 pounds of bluestone in an earthenware or wooden vessel containing about 2 gallons of hot water. This is best done by suspending the bluestone in a muslin bag so that the bottom of the bag is just below the surface of the water. Then, dilute to 25 gallons.

Slake 4 pounds of lime in another suitable vessel, using only enough water to slake well without burning, and dilute this mixture to 25 gallons. Now, keeping the lime solution well stirred, pour these two diluted solutions simultaneously into the spray tank. This makes 50 gallons of 2-4-50 Bordeaux mixture.

In commercial operations where larger quantities are needed at a time, it will be found more convenient to make Bordeaux according to the stock solution method. The only special equipment necessary is two 50-gallon barrels.

1.—Prepare a stock solution of the bluestone by dissolving it at the rate of 1 pound to 1 gallon of water. Fifty gallons of the solution can be made at one time by dissolving 50 pounds of bluestone

in 50 gallons of water in the barrel. If the bluestone is suspended in a bag so that the *bottom is just below* the surface of the water, it will dissolve in cold water in a few hours.

2.—Prepare a stock solution of lime by slaking it and diluting at the rate of 1 pound to 1 gallon of water. For a 50 gallon barrel, weigh out 50 pounds of lime and slake it, using enough water to prevent burning during the process. Then, add water to fill the barrel.

Keep these stock solutions separate until ready to make the Bordeaux according to the formula. For each 100 gallons of Bordeaux, 4 gallons of bluestone solution, 8 gallons of lime solution (well stirred), and 88 gallons of water are required.

Process for a 200 Gallon Tank: Fill the spray tank about two-thirds full of water. Strain into this 16 gallons of the well-stirred milk of lime. While the agitator is running, add 8 gallons of the bluestone solution, and then water to fill the tank.

A new process for making Bordeaux has recently been developed by Mr. F. J. Schneiderhan of the Virginia Experiment Station. This involves the use of the powdered bluestone (known commercially as "Snow"), and the "Chemical Hydrated Lime" which has recently become available on the market. This Bordeaux may be made in the sprayer tank as follows:

Process for a 200 Gallon Tank: (1) Place 8 pounds of the powdered bluestone in the tank strainer and dissolve by running water through it into the tank. By the time the tank is about three-fourths full, all the bluestone should be dissolved.

(2) Mix 16 pounds of the chemical hydrated lime into a thin paste with water and pour into the tank while the agitator is running. Then, complete the process by adding water to fill the tank. This is obviously much more simple than the old process and is recommended when the proper materials are available.

Oil Sprays

Oil sprays are used in orchards for control of scale insects and red mites. Where destruction of these insects is the main object of the treatment, an oil spray is perhaps the most satisfactory material to use. Two general types of oil sprays are used for treating fruit trees, miscible oils and oil emulsions.

Miscible Oil

Oils so treated that they will mix readily with water are termed miscible oils. They are commercial products and their preparation by the grower is not recommended. The rate of dilution of such products for spraying purposes is furnished by the manufacturers.

Lubricating-Oil Emulsions

Lubricating or engine oil emulsions are made in a number of different ways, the essential feature of each being a very thorough mixing of the oil with water by the use of some emulsifying agent. The stock emulsion is then diluted with water to make a spray mixture of the desired strength. Unless otherwise specified, a 3 percent oil spray is recommended. This means that each 100 gallons of the spray solution contains 3 gallons of oil.

Some proprietary oil emulsions are now offered for sale at very reasonable prices. In general, these are quite satisfactory and there is little choice among the different brands, provided the oil content of the product is specified. If this is known, the rate of dilution to make a 3 percent oil spray can easily be determined. If desired, however, growers can prepare an oil emulsion at home according to a standardized formula and make a spray of any desired oil content.

Cold Mix Casein-Oil Emulsion

While several good formulas have been recommended, the cold mix casein-oil emulsion has been most extensively used by West Virginia growers. This emulsion is easily prepared, keeps well, and mixes readily with water. It is not affected by hard water or by lime-sulphur.

Materials Needed: Lubricating oil, commonly known as engine oil, casein, and water are all the materials reqquired. A good grade of lubricating oil with a paraffin base is advised. Diamond Paraffin, Atlantic Red Engine Oil, Junior Red Engine Oil, Ruddo, and other brands have been successfully used.

The casein used may be any one of a number of brands sold under various trade names, such as Kayso, Adheso, Spreado, Calcium Caseinate, etc. Only fresh fine casein should be used. That kept over winter does not usually make good emulsion. A convenient formula for making a small quantity of this emulsion is as follows:

Engine oil	**3 gallons**
Water	**1½ gallons**
Casein	**6 ounces**

Directions: Put the casein into a suitable container and wet with a little of the water to make a paste. Stir in the rest of the water and add the oil. This mixture must now be emulsified. For this purpose a small bucket spray pump is suitable. Simply set the pump in the mixture and force it through the delivery hose back into itself until a creamy emulsion is formed. Or the mixture may be put into a barrel and pumped with the ordinary barrel spray pump. This formula makes 4½ gallons of emulsion which will make a 3 percent oil spray when diluted to 100 gallons with water.

In commercial operations where larger quantities of emulsion

are needed, it is the common practice to make 75 gallons at one mixing in the spray tank according to the following formula:

Engine oil	**50 gallons**
Water	**25 gallons**
Casein	**6¼ pounds**

Steps in Making the Emulsion: 1.—Put about 3 gallons of water into a large bucket and add the casein gradually, stirring constantly until a thin paste free from lumps is obtained.

2.—Run into the spray tank the required quantity of water,—that is, 25 gallons less the quantity used in making the casein paste.

3.—Start the engine and while the agitator is running (not the pump) add the casein paste to the water in the tank.

4.—As agitation of the mixture is continued, pour the oil into the tank.

5.—Start the pump and begin pumping the mixture back into itself through the spray gun.

Use a spray disc with a large opening, and open the gun so that a coarse to solid stream is driven into the mixture. Continue pumping until the mixture appears creamy and no free oil shows on the surface. If 250 to 300 pounds pressure can be maintained, the process will be complete by the time the entire mixture has passed twice through the nozzle.

6.—Pump or run the emulsion into barrels or a tank for storage. When properly made this stock emulsion will not separate for several weeks. If kept until any separation is observed, it can be re-emulsified by pumping the mixture back into itself as in making the original emulsion. It is always advisable to stir the stock emulsion well before any is taken out to dilute for spraying.

How to Dilute for Spraying: Use 4½ gallons of stock emulsion for each 100 gallons of spray. This makes a 3 percent oil spray, since each 4½ gallons of stock emulsion contains 3 gallons of oil.

The best method of making the dilution is to put the required quantity of stock emulsion into the spray tank, and then add the water while the agitator is running. Possible trouble can generally be avoided, however, by adding the emulsion while the tank is being filled, rather than to wait until it is almost full of water.

DUSTS AND DUSTING

Stomach poisons applied in the form of dusts have controlled several of the important orchard insects practically as well as when applied in liquid sprays. Contact insecticides and fungicides have so far been much more effective in the liquid form. Dusting, therefore, cannot yet wholly replace spraying in any orchard, although it may serve as a valuable auxiliary where emergency treatments for chewing insects are required. Dusts will also control some of the diseases of the peach.

FACTORS OF SUCCESSFUL SPRAYING

The three principal factors concerned in spraying which contribute to the desired results are *proper materials, timeliness,* and *thoroughness.* Fundamental to the success of the spraying operation is the use of proper spray materials. Only those which have been demonstrated to be effective are recommended in this circular. Whenever materials other than those advised in the spray programs have been tested and found superior, growers will be informed accordingly.

Fungicides and insecticides to be effective, however, must be properly applied. *Timeliness in making the application* is perhaps the most important factor to be considered, because even a very thorough application of the best materials at the wrong time will fail to produce results. In practically all cases the period for effective applications of fungicides is brief. At most, it is only a few days, while sometimes it is only a day or two. This means that equipment, labor, and materials necessary to cover the trees in a short time must be provided. The continuous running of one sprayer in a large orchard throughout the season is largely a waste of time and money.

Thoroughness of application is second only to timeliness as a factor in determining the success of the spraying operation. Poor spraying may be due to the fact that the labor available is incapable or indifferent, or that weather conditions render good work almost impossible. As a rule, however, it is observed that lack of thoroughness is due to the use of insufficient material. A desire to economize on materials is responsible for this in some cases. On the other hand, many growers fail to appreciate the fact that a definite quantity of material is required to cover a tree properly. This will vary, of course, depending upon the size and age of the tree and the manner in which it is pruned. Average quantities can be given, however, which should afford a better basis for understanding the term thoroughness. Table 2 is based upon careful observations of the quantity of spray material required to cover properly trees in full foliage. Considerably less will be required for trees in the dormant condition.

TABLE 2.—Quantities of Spray Material Required for Trees of Various Ages.

Age of Trees	Apple Trees	Peach Trees
1 to 3 years	¼ to ½ gallon	¼ to 1 gallon
3 to 5 years	½ to 2 gallons	1 to 2 gallons
5 to 6 years	2 to 3 gallons	2 to 3 gallons
6 to 8 years	2½ to 4 gallons	2½ to 4 gallons
8 to 12 years	3 to 5 gallons	3 to 5 gallons
12 to 18 years	5 to 8 gallons	4 to 6 gallons
18 to 25 years	8 to 12 gallons	4 to 6 gallons
25 years and older	12 to 15 gallons	

SPRAY PROGRAM FOR APPLES

Since apple growing is the most extensive branch of the fruit growing industry in West Virginia, a discussion of the apple spray program recommended should be of considerable value to the grower. Materials which may be used for the sprays, the specific diseases and insect pests to be controlled by them, and the approximate times of their application may be found by referring to the spray schedule (Table 3); hence, this discussion is prepared more for the purpose of informing the grower about the facts which determine the choice of materials and the timing of the sprays to be most effective.

Dormant Spray

This spray may be applied at any time during the dormant season, fall, winter, or early spring, except during freezing weather. Since it is of value only for control of certain scale insects, the choice of materials depends upon the kind of scale to be destroyed. If San Jose only is present, winter-strength lime-sulphur, miscible oils, or lubricating-oil emulsion may be used. Lime-sulphur is not very effective against scurfy-scale and oyster-shell scale, however; hence, if either of these scales is present, one of the oil sprays should be used.

A dormant spray is not ordinarly considered necessary, but it may be advisable in some cases. It is recommended where scale has become so bad that it is doubtful whether one treatment at the delayed-dormant stage will control it. Also, since the time available for spraying in this stage is often too short to cover some large orchards with the equipment at hand, it is often advisable to spray at least part of orchard during the dormant period. Thus, if scale is present throughout the orchard, the grower can make sure that all the trees receive one thorough treatment.

Delayed-Dormant Spray

This is one of the most important sprays in the program, since it provides a combination treatment for scales and aphids. Either of two spray materials may be used, winter-strength lime-sulphur or oil sprays. Since either of these will control San Jose scale, the choice of materials is determined by the advisability of taking precautions against a serious infestation of the rosy aphis. In this case, lime-sulphur with nicotine should be used, as this combination is the only spray mixture that has yet been generally recommended. Oil sprays will kill aphids which have appeared on the buds, but none of them has yet been proved to be effective in destroying the eggs which remain unhatched at the time of spraying. The nicotine, however, will kill the insects on the buds, while the strong lime-sulphur destroys the eggs in the stage preliminary to hatching.

TABLE 3.—Schedule of Sprays Recommended for Apples in West Virginia.

Name of Spray	To Control	Time of Application	Materials for 100 Gallons of Spray
DORMANT (Applied only when scale is serious)	*Scales* Red Mite	Late winter or early spring when temperature is well above freezing	Engine-oil emusion, 4½ gals., *or* Tested proprietary oils
DELAYED DORMANT	*Scales* *Aphids* Red Mites (Oil must be used to control the red mite)	When green can first be seen in blossom buds	Lime-sulphur, 12½ gals., *or* Dry lime-sulphur, 30 lbs., *or* Engine-oil emulsion, 4½ gals., *or* Other oils known to be safe (*For aphids add 1 pint of nicotine*)
CLUSTER-BUD (PINK)	*Scab* *Mildew* Leaf spot, or Frog-eye *Curculio* Bud moth and other chewing insects	When majority of cluster buds have separated, or as advised by the Spray Service	Lime-sulphur, 10 qts., *or* Dry lime-sulphur, 7 lbs. *and* Arsenate of lead, 3 lbs.
PETAL-FALL	*Scab* Mildew Leaf spot *Codling moth* Curculio Leaf roller (Red bug)	When most of the petals have fallen	Lime-sulphur, 10 qts., *or* Dry lime-sulphur, 6 lbs. *and* Arsenate of lead, 3 lbs. (*Nicotine, 1 pint, only when red bug is known to be present*)
THREE-WEEKS	*Scab* *Blotch* Mildew *Phoma spot*, or Brooks' spot *Codling moth* Curculio, and other chewing insects	About three weeks after petal-fall, or as advised by the Spray Service	Lime-sulphur, 10 qts., *or* Dry lime-sulphur 6 lbs., *or* Bordeaux mixture, 4-8-100* *and* Arsenate of lead, 3 lbs.
FIVE-WEEKS	*Blotch* Phoma spot Bitter rot *Codling Moth* and other chewing insects	About five weeks after petal-fall, or as advised by the Spray Service	Same as Three-Weeks
SEVEN-WEEKS	Same as Five-Weeks	About seven weeks after petal-fall, or as advised by the Spray Service	Same as Three-Weeks .
SUPPLEMENTARY SPRAYS	Sooty blotch Bitter rot Unusual insects and diseases	Whenever needed. To be announced by the Spray Service	The proper fungicide or insecticide to be announced by the Spray Service

*See discussions of the "three-weeks" and the "five-weeks" sprays, page 26 for information regarding the choice of fungicides.

Timeliness is a factor of great importance in applying sprays to control the rosy aphis. Spraying should be started just as soon as the buds begin to show green. By this time many of the aphis eggs have hatched and the young aphids are assembled on the tips of the buds. Every effort should be made to complete the spray while the buds are still compact on account of the necessity of killing the insects before they obtain protection in the unfolding leaves of the opening buds. Since the buds sometimes develop very rapidly, it is important to be ready to start spraying promptly, and to have equipment and materials sufficient to cover the orchard within the period of time when the spray is most effective.

Again, *thoroughness of application* is absolutely essential. To be effective, the spray must be applied in such manner as to come into direct contact with all the insects; hence, all parts of the tree must be covered with the spray. To accomplish this, it is necessary (1) that trees be kept pruned so as to permit free passage of spray materials to all parts; (2) that machines be used which will deliver the spray where it is needed; (3) that the quantity of spray used be sufficient to insure a thorough covering; and (4) that a system of spraying be adopted which will insure that the spray reaches the undersides of the branches as well as the upper surfaces.

Cluster-Bud Spray

This application, also known as the "pink" spray, is essential for control of apple scab. Unless this spray is applied, growers should not expect satisfactory control of this disease on the more susceptible varieties, since it is applied when the first infections occur. It is less necessary from this standpoint on the more resistant varieties, but it is seldom advisable to omit the application from any variety on account of its value for control of other pests. Furthermore, an outbreak of scab in a season favorable for its development is much more easily prevented if the foliage has been kept free from the disease during the previous year.

The spray should be started just as soon as the majority of the individual buds in the cluster have separated and completed before the blooming period, although it need not be discontinued because a few scattered blossoms have appeared. The time available for this application is brief and spraying should be carried on as rapidly as is consistent with thoroughness.

One spray during the cluster-bud stage is usually all that is necessary under West Virginia conditions. Where scab has been unusually severe, however, it is advisable to make two applications. The first should be made at the "pre-pink" stage—that is, just as soon as the blossom clusters begin to separate. The spray is then repeated in the full "pink" stage, or just before blooming when the buds are practically all showing pink. Arsenate of lead needs to be used in but one of the applications.

Petal-Fall Spray

This spray is very important for control of scab and codling moth and should be applied to all varieties. It should be begun just as soon as most of the petals have fallen. From the standpoint of codling moth control, the period available for making this spray lasts until the calyx lobes begin to close. To continue scab control properly, however, it is necessary that the spray be applied as early in the period as possible.

Three-Weeks Spray

This spray should be applied to all varieties, since it also is very important for continuation of scab and codling moth control. It is the first regular spray for blotch and is probably the first application which is effective in preventing Phoma spot. Choice of the fungicide used is determined by conditions. All varieties which are susceptible to blotch should be sprayed with Bordeaux mixture. Lime-sulphur may be used for other varieties, unless hot weather prevails. In this case, Bordeaux is the proper material, since it is not safe to apply lime-sulphur in bright sunshine when the temperature is above 85 degrees.

The approximate time for this application is three weeks after the petal-fall spray. The exact time is determined by the seasonal development of the pests to be controlled, particularly of codling moth. Since this cannot be specified in advance of the season, the date for the application each year is announced by the Spray Service.

Five-Weeks Spray

This spray should be applied to all varieties, as it is especially important for control of codling moth. The exact date each year is announced by the Spray Service, since it should be applied just before the peak of the hatch of the first brood eggs. This will vary from about four weeks to five and one-half weeks after petal-fall.

Bordeaux should be used on all varieties susceptible to blotch. While a choice of fungicides for other varieties is indicated in the spray schedule, it is strongly recommended that Bordeaux be used. Since this spray usually comes about the middle of June, the weather is generally too hot to apply lime-sulphur with safety. There is so little difference between the cost of the lime-sulphur and that of the 2-4-50 Bordeaux sprays that it is hardly worth considering.

Seven-Weeks Spray

This application is made for the same purposes and under practically the same conditions as the five-weeks spray. On account of the arsenical residue situation, later sprays containing arsenate of lead are not now recommended. This spray, therefore, is advised for all varieties, since it is timed to provide protection against the late hatched first-brood codling moth worms and the first hatched worms

of the second brood. The time of application varies somewhat, but it usually comes about the first week in July. The date each year is announced by the Spray Service.

Supplementary Sprays

In addition to the sprays already discussed, special applications may be necessary to control certain troubles which normally do not appear until late in the season. The most important of such diseases are bitter-rot and sooty blotch. They are irregular in their appearance and special recommendations for their prevention are given when necessary through the Spray Service. Growers are also advised to read the discussions of these diseases on pages 9 and 10 of this circular.

SPRAY PROGRAM FOR PEARS

The pear is an orchard crop of very minor importance in West Virginia, but is given some attention by a few growers. The common pests of the pear are in general the same as those of the apple, although they are usually of less importance. In addition, the pear is subject to two forms of leaf spot caused by fungi which are different from the one that causes the common leaf spot of apples. Control measures, however, are similar.

The spray program for the apple may be used for the pear, except that fewer applications are necessary. Sometimes one thorough application at the petal-fall stage will produce a very clean crop of pears. It is better, however, to arrange the program on the basis of three applications, the cluster-bud, the petal-fall, and the three-weeks spray.

A few varieties of the pear are attacked by the San Jose scale, in which case the dormant treatment may become necessary. Occasionally, also, the pear-slug skeletonizes the leaves late in the summer. This insect is controlled by a light spray of lime-sulphur and arsenate of lead, or by a sulphur-arsenate dust treatment.

SPRAY PROGRAM FOR PEACHES

By properly following the spray program recommended for peaches, it is comparatively easy to produce a high percentage of clean fruit in most sections of West Virginia. Scale is controlled as on other fruits, and the lime-sulphur used will prevent the leaf curl, provided it is applied before the buds swell. Peach scab and brown rot are controlled by the dry-mix or the self-boiled lime and sulphur —the only fungicides now known to be safe for use on peach foliage. The dry-mix is particularly effective and easy to handle. See page 17.

Curculio is controlled by two or three early applications of

arsenate of lead. Until recently, other insects have not been troublesome. Now, however, the oriental fruit moth has become established in some localities in the state. To prevent excessive injury by this insect, it is necessary to supplement the regular schedule by special treatments. These are outlined under the discussion of the oriental fruit moth on page 7 of this circular.

The best results in spraying peach foliage are obtained by using the spray rod with nozzles which produce a fine mist, rather than by the use of the spray gun. When the spray gun is used, it must be so adjusted as to produce a fine mist at all times, since a coarse spray driven into the trees under high pressure may cause excessive injury to the fruit and foliage.

The sprays recommended for peaches in West Virginia are given in Table 4, together with the insect pests or diseases for the control of which they are applied and the time of application.

TABLE 4.—Schedule of Sprays Recommended for Peaches in West Virginia.

Time of Application	To Control	Materials for 100 Gallons of Spray
1.—Dormant season before buds have begun to swell.†	Leaf curl San Jose scale‡	Lime-sulphur, 12½ gallons**
2.—Petal-fall (As soon as all the petals have dropped)	Curculio	Arsenate of lead, 2 lbs., *and* Stone lime, 8 lbs. (See page 13 of this circular)
3.—Shuck-fall (As soon as most of the shucks are off)	Curculio	Same as Number 2
4.—Three weeks after Number 3	Curculio Scab	Self-boiled lime and sulphur, *or* Dry-mix, 16 lbs. *and* Arsenate of lead, 2 lbs.††
5.—One month before ripening	Brown rot Scab	Self-boiled lime and sulphur, *or* Dry-mix, 16 lbs.
6.—Two weeks after Number 5. (For late varieties only)	Brown rot Scab	Same as Number 5

*After the dormant application, dust treatments may be substituted for the liquid sprays.

†To obtain the best results in controlling leaf curl and San Jose scale, as well as to save time in the spring, it is better to apply this spray during the late fall. (See page 12 of this circular.)

‡If the peach lecanium (terrapin scale) becomes serious, apply one of the oil sprays in the spring, prior to the swelling of the buds, when the temperature is above 40 degrees.

**If no scale is present, the strength of the lime-sulphur may be reduced one-half.

††Observe caution on page 18 of this circular about adding lime when using arsenate of lead with dry-mix.

SPRAY PROGRAM FOR PLUMS AND CHERRIES

Recommendations for spraying plums and cherries in West Virginia are given in Tables 5 and 6.

TABLE 5.—Schedule of Sprays Recommended for Plums in West Virginia.

No. of Spray	Time of Application	To Control	Materials for 100 Gallons of Spray
1	Dormant season	San Jose scale	Lime-sulphur, 12½ gallons
2	Immediately after the petals have fallen	Curculio Leaf spot	Lime sulphur, 10 quarts, and Lead arsenate, 2 pounds
3	One week after Number 2	Curculio Leaf spot	Same as Number 2
4	Two to three weeks after Number 3	Curculio Leaf spot	Same as Number 2
5	One month before ripening*	Brown rot	Self-boiled lime and sulphur, *or* Dry-mix, 16 pounds

*In case of warm, damp weather it is advisable to repeat Spray Number 5 within two weeks to give additional protection against brown rot.

TABLE 6.—Schedule of Sprays Recommended for Cherries in West Virginia.

No. of Spray	Tme of Application	To Control	Materials for 100 Gallons of Spray
1	Dormant season	San Jose scale	Lime-sulphur, 12½ gallons
2	Immediately after the petals have fallen	Curculio Leaf spot	Lime-sulphur, 10 quarts, and Lead arsenate, 2 pounds
3	One week after Number 2	Curculio Leaf spot	Same as Number 2
4	Two to three weeks after Number 3*	Curculio Leaf spot Brown rot	Same as Number 2
5	Immediately after fruit is harvested.	Leaf spot	Lime-sulphur, 10 quarts

*In case of warm, damp weather it is advisable to make an additional application two weeks after Number 4, using lime-sulphur without poison, to give additional protection against brown rot.

Discussion of Recommendations for Plums and Cherries

Some varieties of cherries are not attacked by San Jose scale, while others are seldom infested to the extent that a dormant spray is necessary. Plums, however, may be injured severely, if scale is not kept under control. The most important insect pest of both plums and cherries is the curculio which may be controlled by the sprays indicated in the schedules (Tables 5 and 6). Nicotine at the rate of 1 pint to 100 gallons may be added to any of the sprays to destroy aphids whenever serious injury is threatened. (See discussion of Cherry and Plum Aphids, page 8.) Occasionally, the pear-slug attacks the cherry late in the season and causes considerable injury by skeletonizing the leaves. This insect is controlled by a light spray of lime-sulphur and lead arsenate, or by a sulphur-arsenate dust treatment. (See discussion of Rose-bug or Rose-chafer, page 8.)

The most important disease of both plums and cherries is brown rot, which does not usually appear until rather late in the season. The sprays for its prevention are indicated in the schedules. (See also the discussion of Brown Rot, page 11.)

GENERAL DISCUSSION OF METHODS AND EQUIPMENT

No one method can be advised for all sprayers, since different conditions and individual preference must be considered. Where the size of the trees is not too great, better work will certainly be done by operators on the ground than by men in a tower or on the spray tank. One man, at least, must move around the tree and spray from beneath the lower branches. This is especially important in aphis control.

Granted the same activity and intelligence in the operator, at least as good results, and much more speed, can be obtained with the spray gun than with the rod and nozzles. A good combination in many cases will be one man with a gun and one with a rod. The drawback to the use of the rods with ordinary nozzles is their lack of capacity to permit fast work and of driving power to carry the spray through the trees. Rods equipped with specially designed nozzle-heads which deliver under high pressure a volume of spray equal to that of the spray gun may now be obtained.

The necessity of having spray equipment sufficient to cover the orchard thoroughly during the period within which sprays are effective can not be over-emphasized. Unless this be done, growers should not expect the best results from the spray program. It has already been explained that the period for effective applications of fungicides is brief, sometimes not more than a day or two for one variety of apples. While conditions vary so widely that no definite statement can

be made, it may be said that provision should be made to cover an orchard containing several varieties within a week. To do this, a good power sprayer with pump capacity sufficient to maintain one spray gun is ordinarily required for every thirty to forty acres of orchard under average conditions in the state.

Hose leads of length sufficient to permit the spray rig and the men to keep out of the wind-drift will readily be admitted to be essential. It should not be necessary to say that the outfit should be in good repair in every particular. The labor of spraying is unpleasant enough at the best. Avoidable features that cause discomfort are sure to add to the dissatisfaction and reduce the efficiency of the operators.

The equipment of any large orchard may well include one or more dusting machines to supplement the work of the spray outfits. Those interested in dusting would do well to get special information, and to read West Virginia Experiment Station Bulletin 209, Dusting vs. Spraying in the Apple Orchard.

INDEX

	Page
THE WEST VIRGINIA SPRAY SERVICE	3
ORCHARD INSECTS	4 to 8
San Jose and other Scales	4
Peach Lecanium	4
Apple aphids	4
Apple red-bug	5
Leafhoppers	5
Canker-worms	5
The bud-moth	5
The curculio	6
The pistol case-bearer	6
Mites	6
The codling moth	6
Apple leaf roller	7
Lesser apple worm	7
Miscellaneous caterpillars	7
Oriental fruit moth	7
The cherry leaf-beetle	8
Cherry and plum aphids	8
Rose-bugs or rose-chafers	8
ORCHARD DISEASES	8 to 12
Apple scab	8
Bitter-rot	9
Black-rot	9
Apple blotch	10
Sooty blotch and fly-speck	10
Phoma spot	10
Powdery mildew of apples	11
Spongy dry-rot	11
Brown-rot	11
Peach scab	12
Peach leaf curl	12
COMMON INSECTICIDES AND FUNGICIDES	12 to 20
Arsenate of lead	12
Nicotine	13
Derrisol	14
Concentrated lime-sulphur	14
Dilution table for lime-sulphur	16
Dry lime-sulphur	16
Self-boiled lime and sulphur	16
Dry-mix sulphur lime	17
Bordeaux mixture	18
Oil Sprays	19
Miscible oil	19
Lubricating-oil emulsions	20
Cold mix casein-oil emulsion	20
DUSTS AND DUSTING	21
FACTORS OF SUCCESSFUL SPRAYING	22
SPRAY PROGRAM FOR APPLES	23
SPRAY PROGRAM FOR PEARS	27
SPRAY PROGRAM FOR PEACHES	27
SPRAY PROGRAM FOR PLUMS AND CHERRIES	29
GENERAL DISCUSSION OF METHODS AND EQUIPMENT	30

Why Guess?

or Gamble

as to—

—the proper time to spray

—the proper materials to use

—the amount of spray required

—the best method of application

WHEN trained specialists are at your service to help you solve your spraying problems? The College of Agriculture, West Virginia University, through its Extension Service maintains a field laboratory in the heart of the main fruit growing section during the spraying season to observe at first hand orchard conditions and seasonal changes, and study insect and disease development as it takes place in the orchard.

Recommendations based on these field studies are prepared in mimeograph form and will be mailed free to any one interested.

In case of special problems not covered by this circular and the Spray Notices, write, telegraph, or phone for further information.

"Let Your College Serve You."

College of Agriculture

W. Va. University **Morgantown, W. Va.**

CIRCULAR 55 MAY, 1930

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

Blackberry Jelly, Blackberry Jam, and Cherry Preserves

by HAZEL CAMERON

UNIVERSITY OF ARIZONA LIBRARY

BLACKBERRY JELLY*

Essentials for Jellying

FOR MAKING blackberry jelly, as for any other jelly, four things must be present in the fruit juice, or must be added to it: water, pectin, acid, and sugar.

Water will be supplied by the berries as they cook, and none need be added for making the first extraction of juice. For all later extractions water must be added.

Pectin—What Is It?

Pectin is the substance which gives to fruit its jellying property. It is found in fruits naturally or is formed when the fruit is boiled with water, as in making an extraction of fruit juice for jelly. Fruits like apples, currants, and grapes are rich in pectin; peaches and pears are poor in pectin. Unripe fruits contain more pectin and therefore make a jelly of better texture. The flavor, however, is much less desirable. Not more than one-fourth of the blackberries should be under-ripe.

Testing for Pectin

A simple test for pectin can be made on any fruit juice by means of alcohol, which will show whether or not the juice will make good jelly. This test should always be made on juice to be used for jelly, in order to avoid wasting both sugar and time on juice which will not make jelly. Denatured alcohol can be purchased at any drug store for this test, which is made as follows:

Put 1 teaspoonful of cooked, cooled fruit juice in a shallow cup or dish. Add 1 teaspoonful of alcohol. Mix by gently tipping the cup. Do not stir.

*The information contained in this circular is based on a scientific study of the preparation of preserves under various conditions, reported fully in Bulletin 234 of the West Virginia Agricultural Experiment Station, "Standardization of Cherry and Blackberry Preserves and Blackberry Jelly," by Hazel Cameron and Ruth B. Burns.

If the juice contains enough pectin to make good jelly, a clear, thick, jelly-like mass will form in the bottom of the cup almost at once. The results of this test can be described as follows:

(1) The pectin test is "*very good*"—
If all of the juice becomes solid, so that very little or no liquid is left in the cup.

(2) The pectin test is "*good*"—
If a thick, jelly-like mass forms almost at once.

(3) The pectin test is "*fair*"—
If a few large lumps of jelly form.

(4) The pectin test is "*poor*"—
If only a few flakes of jelly form. This juice will not make good jelly, unless apple juice or other source of pectin is added.

The alcohol test, besides being a helpful test for the jelly-making properties of a given fruit juice, can also be used to determine how much sugar to add in making jelly, as will be shown later.

Acid for Jellying

Acid is present in blackberries. If they are picked at the proper time it will be present in large enough quantity to make good jelly. Blackberries which are dead ripe will not make good jelly because they do not contain enough acid and pectin. On the other hand, if the berries are too green, the flavor is very poor. Hence, for jelly or jam, pick blackberries when some of them still show red spots. From 1/10 to 1/4 of the berries should be partly red (not green), and the remainder black. If this precaution is taken, no additional acid will be needed. *Small* amounts of additional acid, such as 5 percent tartaric acid, or lemon-juice, do no harm; larger amounts spoil the natural blackberry flavor.

When in doubt as to the necessary acidity of a given juice for jelly, one of the following simple tests is often helpful:

1. Mix 1 teaspoonful of lemon juice with 9 teaspoonfuls of water in a cup. Compare the taste of this with the blackberry or other juice to be tested. If the fruit juice is as sour as the diluted lemon-juice, it will make satisfactory jelly. In tasting for acid, it is necessary to disregard fruit *flavor* and concentrate on *sourness*.

2. The alcohol test for pectin may be modified for acid. Test the juice for pectin in the usual way. Then add to 1 cup of the juice, ¼ teaspoonful of lemon-juice, or 5 percent tartaric acid. Mix well. Repeat the alcohol test on this acidified juice. If this test is *better* than it was before, the juice needs more acid. In this case, to each pint of the juice used for jelly, add ½ teaspoonful of lemon-juice or acid. If the test is worse or shows no change, acid will not improve the juice for jelly.

Sugar

Blackberry juice contains some sugar, but not enough to make good jelly. How much should be added, and at what point in cooking?

The pectin test has been found very helpful in determining how much sugar to add to make good jelly. Too much sugar in proportion to the pectin present will give a very soft, sweet jelly which may not even set into a true jelly. Too little sugar, besides making a sour jelly and reducing the yield, gives a firmer, tougher texture than is desirable.

Experiments with blackberry juice at the State Agricultural Experiment Station show that the following amounts of sugar gave good results:

1. If the pectin test is *"very good"* and the juice has enough acid, 1⅓ to 1½ cups sugar to each cup of juice give the best jelly.
2. If the pectin test is *"good"*, 1¼ to 1⅓ cups of sugar per cup of juice.
3. If the pectin test is *"fair"*, ¾ to 1 cup sugar per cup of juice.
4. If the pectin test is *"poor"*, do not use the juice for jelly.

It is more accurate to weigh the juice and sugar, and more easily done, if scales are available. By weight, the amounts of sugar are as follows:

Pectin test "very good"—sugar 1¼ to 1⅓ ounces per ounce of juice used.

Pectin test "good"—sugar 1 to 1¼ ounces per ounce of juice used.

Pectin test "fair"—sugar ¾ (or slightly less) the weight of juice.

When should the sugar be added? For small amounts of jelly, little difference was found for practical purposes in adding the sugar to the cold juice or later. Too long boiling of the juice before the sugar is added is not desirable. A very satisfactory method is to add the sugar, and acid, too, if it is needed, just after the juice starts boiling.

When is the Jelly Done?

There are three ways of telling when jelly is finished, and of the three, the last will give most uniform results.

(1) The "spoon jelly test". This is the familiar test of the household, of allowing the jelly to drip from a spoon. As soon as the drops "set" into a jelly at the edge of the spoon, the jelly is done. A silver spoon should be used, as a wooden spoon appears to give the test while the jelly is still too soft, and a metal spoon will tarnish. This test, in the hands of one experienced in using it, often gives very good results; but too many mistakes occur, making the jelly too soft or too stiff, to recommend the test very highly, especially for those unfamiliar with appearance of the jelly drops.

(2) Cooking to temperature. A Fahrenheit thermometer such as is used for candy, icings, etc., or a Centigrade thermometer on which the boiling point of water is 100°, can be used for jelly quite easily and gives better results than the spoon test. A few precautions are necessary to get good results, however.

First, be sure the bulb of the thermometer is covered by the jelly.

Second, be sure the bulb of the thermometer does not touch the

bottom of the kettle, but is raised from it by a metal piece on the thermometer.

Third, stir the jelly just before reading the thermometer.

Fourth, be sure to place the thermometer in the center of the kettle. Hold it upright, and stoop down to read it so that the eyes are on a level with the top of the mercury line in the thermometer.

Fifth, if jelly is made in a locality quite high above sea level, as among the mountains, be sure to correct the temperature for the elevation (number of feet above sea level).

When blackberries were picked before they became too ripe, and when the correct amount of sugar was added as determined by the pectin test, good jellies were made at the Experiment Station at temperatures from 101° to 105° Centigrade or 214° to 221° Fahrenheit. Jellies at 105° C. were less desirable than below this temperature, the average temperature therefore being between 102° to 103° C., or 216° to 217° F. This is for an elevation of 900 feet. For sea level, this would be approximately 103° to 104° C., or 217° to 219° F. The temperature at which water boils varies of course with the elevation; on a mountain it may boil at 96° C. instead of 100° (205° F.). Similarly, jelly will boil at a lower temperature and hence be finished at a lower temperature on a mountain top. For differences in elevations less than 1000 feet, the change is small; smaller than the range of temperature for good jelly. If the elevation is more than 1000 feet above sea level, subtract ½ degree C. or 1 degree F. for each 500 feet above sea level. (See Table 1.)

TABLE 1.—*Corrected Jelly Temperatures for Different Elevations Above Sea Level*

Elevation above Sea Level	Temperature at Which Jelly is Finished	
	Centigrade (degrees)	Fahrenheit (degrees)
Sea level	103 -104	217 -219
500 feet	102½-103½	216½-218
1000 feet	102 -103	215½-217
1500 feet	101½-102½	214½-216½
2000 feet	101 -102	214 -215½
2500 feet	100½-101½	213 -215
3000 feet	100 -101	212 -214

Cooking to Weight

This is the most accurate method of finishing jelly and one of the easiest to use when it becomes familiar. Weigh the kettle in which the jelly is to be cooked, and the sugar to be added, as determined by the alcohol-pectin test. From Table 2 find the end weight of blackberry jelly for the given amount of sugar. Add this weight to the weight of the kettle, and cook the jelly until this total weight is reached, when the kettle is placed on the scales. Usually, after a little experience, only one or two trial weighings are necessary to reach the correct weight.

The weights given in Table 2 are calculated from experimental results obtained at the State Agricultural Experiment Station and have been determined *only* for blackberry jelly and *only* for the weight of sugar as determined by the alcohol-pectin test. When these weights are used the jelly will contain 62.5 percent sugar.

TABLE 2.—*End Weight of Blackberry Jelly for Different Weights of Sugar*

Weight of Sugar	End Weight of Jelly
6 ounces	9½ ounces
8 "	12¾ "
10 "	16 "
12 "	19 "
14 "	22 "
16 "	25½ "
18 "	28¾ "
20 "	32 "
22 "	35 "
24 "	38 "
26 "	41½ "
28 "	44¾ "
30 "	48 "
32 "	51 "
34 "	54 "
36 "	57½ "
38 "	60¾ "
40 "	64 "
42 "	67 "
44 "	70 "
46 "	73½ "
48 "	76¾ "
50 "	80 "

The procedure recommended for blackberry jelly is therefore as follows:

Selecting the Fruit

Be sure the berries are not overripe and yet not green. One basket out of every 4 or 5 should be black and *red* (not green).

Preparation of the Juice

Wash the berries under a spray of water if possible. Drain in a colander until water no longer drips from them. Heat to boiling in a covered kettle, without adding any water. Stir occasionally to prevent sticking. Mash with a wire potato masher and simmer gently for 10 minutes or until very soft. Drain in a heavy bag overnight. Return the pulp to the kettle with an equal weight of water (enough to cover), simmer for 10 minutes, and again drain overnight. Do not squeeze the bag, for this makes cloudy juice, and the second extraction gets more of the jellying substances in a clear form.

If berries are plentiful, the second extraction may be omitted, though some jelly stock is lost in this way. To shorten the time, the second extraction may be drained only 4 hours. Not all of the juice is recovered at this time, but the bulk of it is. Squeezing the bag is to be avoided even in this case as it will make cloudy jelly. The first and second extractions can usually be mixed and made into jelly.

For some fruits a third extraction, made in the same manner as the second, is profitable. For blackberries a third extraction usually is poor in pectin and not worth while. If the berries are very rich in pectin, it can be tried, but the juice should be tested with alcohol to see whether it contains enough pectin for jelly.

Testing the Juice

Test for pectin and for acid as described above. This is very important in determining the amount of sugar to be used and should not be omitted.

Finishing the Jelly

Make up not more than 4 to 6 cups of juice into jelly at one time.

Weigh the kettle to be used, then the sugar as determined by the alcohol test for pectin. From Table 2 find the end weight of jelly for this amount of sugar. Add this weight to the weight of the empty kettle. Heat the juice to boiling. Add the sugar, and boil *rapidly,* until the weight reaches the weight determined above.

Remove the scum as it forms.

Stir occasionally.

Boil as rapidly as possible without letting it boil over. Use a kettle large enough so that it will not be over ½ full of jelly.

When the jelly reaches the desired weight, remove from the fire and pour into *hot, scalded* jelly glasses which have been lifted from hot water with a sterile fork or spoon. Do not touch the inside of the glass.

If desired, a little paraffine can be cut up in the bottom of the jelly glass before the jelly is poured. If the jelly is *hot* when poured in, it will melt the paraffine, which rises to the top and seals the jelly.

If these steps are carefully followed with blackberry juice, the results should be a clear, bright, sparkling jelly which quivers but does not run on a plate; cuts easily with a spoon, leaving sharp edges where cut; is neither sticky, gummy, nor tough; and is of natural blackberry flavor and sweetness, scoring 90 or above by the accompanying score.

Scoring Jelly

If jelly is judged or scored even for home use, its faults can often be corrected. The following score card (No. 1) is simple and complete. If the jelly is to be offered for sale, the score used should take note of the container and label used, and score card No. 2 is to be preferred.

Jelly Score Card No. 1

APPEARANCE		20 points
Transparency	5	
Color	5	
Shape	5	
Glistening	5	
TEXTURE		35 points
Tenderness	10	
Quivering	10	
Consistency	10	
Holding angles	5	
FLAVOR		30 points
Naturalness	10	
Sweetness	10	
Strength	10	
KEEPING QUALITIES		15 points
Total		100 points

Jelly Score Card No. 2

CONTAINER		10 points
Size and shape	2	
Clearness of glass	2	
Label, size, position, attractiveness	2	
Cap, convenience, perfect seal	2	
Completeness of fill	2	
APPEARANCE OF JELLY		15 points
Color and transparency	5	
Shape	5	
Glistening cut surface	5	
KEEPING QUALITIES		15 points
Freedom from mold and spoilage	5	
Freedom from sugar crystals	5	
Freedom from weeping	5	
TEXTURE		30 points
Tenderness	8	
Consistency	8	
Quivering	8	
Holding angles when cut	6	
FLAVOR		30 points
Sweetness	10	
Naturalness	10	
Strength	10	
Total		100 points

Jelly Failures and Their Cause

The following is a list of common jelly failures and their cause:

1. *Mold or Fermentation*
   Containers not sterilized by boiling in water.
   Careless handling of container after sterilization.
   Imperfect seal or container.
   Too little sugar.
2. *Color Dark; Cloudy*
   Juice squeezed rather than allowed to drip.
   Juice not strained through thick cloths.
   Overcooking.
3. *Sugar Crystals*
   Too much sugar or too little acid or pectin.
   Sugar added too near end of cooking process.
   Imperfect seal.
4. *Weeping*
   Too much acid in proportion to pectin present.
5. *Jelly soft*
   Juice poor in pectin because too ripe or unsuitable for jelly-making.
   Too much sugar.
   Insufficient cooking.
6. *Jelly stiff*
   Too little sugar.
   Too high temperature.

7. *Jelly Tough and Gummy*
   Overcooked.
   Too little acid.
8. *Jelly Syrupy*
   Too much sugar.
   Too little pectin (fruit too ripe or unsuitable).
   Long, slow cooking (destroys pectin).

BLACKBERRY JAM

GOOD blackberry jam is simply good blackberry jelly plus some seeds and pulp. The same principles apply in making it as in blackberry jelly. It is just as important to pick the berries before they become too ripe, and just as important to test the juice for pectin. To do this, wash a few of the blackberries to be used for jam, cook until soft in a covered kettle without any additional water, strain through a cloth. Cool the juice and test for pectin as described under "Blackberry Jelly."

TABLE 3.—*Final Weight of Jam for Different Weights of Sugar*

Item	Weight in Ounces																			
Sugar ...	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
Final Wt. of Jam..	9½	13	16	19½	22½	26	29	32½	35½	39	42	45½	49	52	55	58½	61½	65

Amount of Sugar

For a *good* pectin test, with berries picked so as to give a satisfactory acid content, from 1¼ to 1½ times as much sugar as berries by weight gave good jam when made according to the method given below. The best jam contained 1⅓ times as much sugar as berries by weight. For a *fair* pectin test this would mean 1 to 1¼ times as much sugar as berries; for a *very good* test, 1½ times.

It is both easier and more accurate to add sugar by weight rather than by measure. Roughly, these weights correspond to 1⅘ cups sugar to 1 cup of ground blackberries, when the pectin test is good.

When is Jam Finished?

By the spoon jelly test described under blackberry jelly, the "jellying" point in blackberry jam with berries of good pectin test and sufficient acid, came between 101 and 102½ degrees Centigrade (213.8° to 216.5° Fahrenheit). The best jam was that cooked to 102° C. (215.6° F.) at 900 feet elevation. For elevations above 1000 feet correct this temperature as described under jelly.

Cooking to weight as described under blackberry jelly gave excellent results. For jam made from berries showing a good pectin test, with 1¼ to 1⅓ times as much sugar as berries, the best jam was that cooked until it contained 61 to 62 percent of sugar. Table 3 gives the final weight to be reached for each amount of sugar used, when 1¼ to 1⅓ times as much sugar is used as berries. To this final weight, add the weight of the empty kettle and cook the jam until weight of kettle plus weight of jam reaches this point.

Method for Blackberry Jam

The method advocated for making blackberry jam is therefore as follows:

Pick blackberries so that 1/10 to 1/4 of them are red, turning to black *(not green)*; the rest, black.

Remove stems and leaves.

Wash berries in a sieve or colander.

Drain well until water no longer drips from them.

Grind through a good grinder to make a uniform, smooth product.

Weigh.

Cook not over 4 quarts at a time in a kettle large enough so that the berries fill it not over one-half full. No water need be added when the berries are ground unless they are very dry, when not over 1 cup of water to each 4 quarts of berries may be added.

Cook covered until soft (5 to 10 minutes), stirring just enough to prevent sticking.

Strain a small amount through a cloth, cool this juice, and use it to test for acid and pectin. (See Blackberry Jelly).

For a *very* good pectin test, add 1½ ounces of sugar for each ounce of ground berries.

For a *good* pectin test, add 1⅓ ounces of sugar for each ounce of ground berries.

For a *fair* test, add 1 to 1¼ ounces of sugar for each ounce of ground berries.

Remove about ⅓ the weight of ground berries: rub this through a sieve or colander to take out the seeds. Return the pulp to the rest of the berries.

Add sugar as determined by the pectin test.

From Table 3, find the weight of jam when finished which corresponds to the amount of sugar used. (These weights are based on the amount of sugar added according to the pectin test; therefore be sure to follow this test.)

Add the weight of the empty kettle.

Boil rapidly until this weight is reached, stirring just enough to prevent sticking.

Pour at *once* into clean glasses or jars which have been sterilized by boiling for 10 minutes in enough water to cover. Lift the jars or glasses from the water with a long fork or spoon dipped in boiling water. Do not touch the inside of the glass with the hands or a cloth.

If screw-cap jars are used, fill the jar full, immediately screw on the cap, and invert for 10 minutes to sterilize the cap which cannot be boiled because of the paper lining. Be sure to turn the jars upright again before the jam gets cold and sticks to the cap.

Use no paraffine on screw cap jars.

Melted paraffine may be poured over other glasses or containers at once.

Scoring Jam

Score your own jam to see how good a product you are making. The accompanying score card is the one used at the West Virginia Agricultural Experiment Station.

To carry the Mountain State Brand label, all jam must score 90 or above from a sample sent to the Agricultural Experiment Station, Morgantown, W. Va.

CHERRY PRESERVES

What is a Preserve?

WHAT constitutes a preserve and how much sugar it shall contain is defined by the United States Government as follows: "A preserve is the clean, sound product made by cooking to a suitable consistence properly prepared fresh fruit, cold pack fruit, canned fruit, or a mixture of two or all of these, with sugar or with sugar and water. In its preparation not less than 45 pounds of fruit are used to each 55 pounds of sugar. A product in which the fruit is whole or in relatively large pieces is customarily designated a preserve rather than a jam."

Ideal Cherry Preserves

But not all preserves corresponding to this standard are good, because "suitable consistence" is not defined and varies widely with personal taste. The opinions of trained judges and tasters who know what the majority of people want when purchasing preserves, show that an ideal cherry preserve should consist of whole, plump cherries, with tender, unshriveled skins, of a natural cherry color and flavor and an agreeable tartness, in a heavy, clear, pink or red sugar syrup, which is not caramelized or browned by overheating, is not a jelly, and yet is thick enough so that it will not "run" on a plate. Considerations of importance in making such a preserve are: (1) variety, (2) ripeness of cherries, (3) amount of sugar, (4) method of adding sugar, and (5) temperature of cooking.

The making of an ideal cherry preserve falls into the following steps:

Selection of Fruit

Large cherries with thick meat and small seed are best. Some of the early sour cherries, as Early Richmond, which have a rather large seed and soft thin pulp, shrink badly and are better canned for pies, or mixed whole, or ground with other fruit in the form of a marmalade. Sweet cherries, if used, usually require small amounts of lemon-juice or other acid to bring out the flavor, and may have undesirably tough skins. Cherries for preserves should be fully ripe, since underripe fruit gives a pale color (except in very dark varieties) and tends to shrivel badly. As much as one-tenth of the cherries may be partly ripe without spoiling the product. Cherries preserve their plumpness better for preserves if they are soaked in cold water 4 to 8 hours or overnight before pitting.

Amount of Sugar

Equal weights of pitted cherries and sugar give very good results, fulfilling the government requirements and making a product of satisfactory sweetness. More than an equal weight of sugar usually makes too sweet a cherry preserve. Weighing is more accurate than measuring, since a cup of pitted cherries weighs more or less, depending on how tightly they are packed.

Methods of Adding Sugar

Most preserves are made by dropping the fruit into boiling sugar syrup and cooking to the desired consistency; but cherries are so soft and contain so much water that this yields too much syrup of a very thin consistency unless boiled down—a process which shrivels the fruit badly. Therefore dry sugar is added to the cherries as follows: The pitted cherries are weighed, and one-third their weight of sugar is added and allowed to stand in a cool place for 2 to 4 hours. The cherries are then drained off, and the same weight of sugar as before is added to the syrup which is left. This is heated to boiling, the cherries are added, and the whole is heated again until it just boils through. Again let stand 2 to 4 hours or overnight in a cool place. Again drain out the cherries, add the rest of the sugar to the syrup, heat to dissolve, add the cherries, heat to boiling, let stand 2 to 4 hours, and complete the cooking. This helps to keep the cherries whole and plump and is very important. The additions of sugar in one-third portions should be planned so that the cherries stand overnight once during the process, and 2 to 4 hours between the other two additions of sugar.

Finishing the Preserves

Since cherries do not usually make a jelly, the spoon jelly test is of no help in telling when cherry preserves are done. Cooking to a definite temperature (106° to 106.5° Centigrade at 1000 feet elevation, or 223° to 224° Fahrenheit) is helpful but not always accurate, since the cherries frequently do not heat through evenly. Cooking to weight avoids this difficulty as well as the trouble of correcting the temperature for elevation or altitude, and is recommended. If the preserves are cooked rapidly until the weight is from 83 to 85 percent of the weight at the beginning, a very good consistency is obtained. Thus, if the pitted cherries used weigh 16 ounces and 16 ounces of sugar is added, the total weight is 32 ounces. The weight at the end should then be $85/100 \times 32$, or 27 ounces. The weight of the kettle must be added to the 27 ounces to get the total weight. The cherries are thus cooked rapidly, weighing occasionally until the kettle records this weight when placed on the scales. (See Table 4.) With practice, this weight is often obtained at the first or second trial.

The cherries will be more plump and have a slightly better consistency if, after cooking as above, they are allowed to stand covered in the cooking kettle in a cool place until cold, stirring occasionally. They can then be sealed without reheating into sterile jars.

This method yields a preserve with considerable juice. Further cooking, however, merely shrinks and toughens the cherries, and should not be tried. It is better, if less juice is preferred, to take out from one-fourth to one-half cup of juice from a 2-pound lot of preserves when sealing the preserves into jars, using this juice as a sauce for ice cream or puddings or in lemonade.

Use of Additional Pectin

The preserves may be thickened slightly if desired by means of

Certo or home-made apple-pectin solutions.* One and one-half tablespoonfuls of Certo or 3 or 4 tablespoonfuls of home-made pectin, depending on its strength, for each pound of pitted cherries, can be added to the preserves just after taking the finished product from the fire, stirring frequently during the cooling process and sealing as above. This yields usually a consistency slightly thickened but not jellied. If too thick, less can be used, since the amount to be used depends on the cherries as well as on the strength of homemade apple-pectin solutions.

The Final Recipe Recommended for Cherry Preserves Is as Follows:

Soak cherries before pitting, in cold water, 2 to 4 hours or overnight. Pit, and weigh. Make up only 1 to 2 pounds of cherries into preserves at one time. Add sugar equal to one-third weight of the pitted cherries. Allow to stand in a cool place for 2 to 4 hours covered. Drain out the cherries, add another one-third weight of sugar to the juice, heat to boiling, add the cherries, and reheat until the the mass just boils through.

Let cherries stand covered in a cool place again for 2 to 4 hours or overnight. Repeat this process with the final one-third weight of sugar. Arrange to let the cherries stand overnight with one portion of sugar, and from 2 to 4 hours with the other two portions.

Boil rapidly until the final weight equals the weight of kettle plus 83 to 85 percent of the weight of cherries and sugar at the beginning. (See Table 1.)

Let stand in kettle until cold, stirring frequently.

Seal into sterile jars, keeping out from 1/4 to 1/2 cup of the syrup if the product has too much juice.

One and one-half tablespoonfuls Certo or about 4 tablespoonfuls homemade apple-pectin may be added to the preserves when taken from the fire. This gives a slightly thicker product.

TABLE 4.—*End Weight of Cherry Preserves for Given Weight of Cherries Used*

Weight of Cherries	Weight of Sugar Added	Weight when Done†
12 ounces	12 ounces	20 ounces
13 "	13 "	22 "
14 "	14 "	23½ "
15 "	15 "	25½ "
16 "	16 "	27 "
17 "	17 "	29 "
18 "	18 "	30½ "
19 "	19 "	32 "
20 "	20 "	34 "
21 "	21 "	35½ "
22 "	22 "	37 "
23 "	23 "	39 "
24 "	24 "	40½ "
25 "	25 "	42½ "
26 "	26 "	44 "
27 "	27 "	46 "
28 "	28 "	47½ "
29 "	29 "	49 "
30 "	30 "	51 "
31 "	31 "	52½ "
32 "	32 "	54 "

†Add the weight of the empty kettle to this.

*Write to Agricultural Extension Division, Morgantown, W. Va., for instructions concerning homemade apple pectin.

Circular 56 September, 1930

Feeding Dairy Cows

by H. O. HENDERSON and JAMES V. HOPKINS

Alfalfa--Choicest of Legume Hays

UNIVERSITY OF ARIZONA LIBRARY

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

GUIDES IN FEEDING DAIRY COWS

1.—Feed all the roughage that the cows will eat up clean. Legume roughage is best.

2.—Be sure that the ration is properly balanced. Then feed the grain mixture in proportion to the milk yield. For the average herd, feed one pound of grain for each 3½ pounds of milk produced. A variety of grains in the mixture is desirable.

3.—Feed some succulent feed like silage or roots.

4.—During the dry season of the year supplement the pastures by feeding silage or some green crop together with a little grain.

5.—If the cows show a tendency to become fat, reduce the amount of grain, or roughage, or both.

6.—Give the cows plenty of pure water.

7.—Feed regularly and let them get salt daily.

Feeding Dairy Cows

by H. O. HENDERSON AND JAMES V. HOPKINS

WHILE there is a decided need for much better cows in the state, it is true, nevertheless, that if the cows which are already here were fed and cared for more carefully, the production would be greatly increased. The production in many cases could be increased from one-third to one-half, with very little additional cost, by following a few simple rules of better feeding. Better feeding methods constitute the quickest and surest way for the West Virginia dairyman to increase the profits from his dairy.

FUNDAMENTALS OF FEEDING

In order to feed intelligently it is necessary for a dairyman to understand some of the terms used in feeding dairy cows, and to understand just what feed is made of and how it is used by the cow.

Few dairy farmers in West Virginia have not heard of the terms "protein," "carbohydrates," and "fat," or seen them printed on a tag attached to a bag of feed. But in order to avoid haphazard feeding it is necessary to know the meaning of these terms. In discussing "composition" and other feed terms we must make use of the chemical terms, "elements" and "compounds."

ELEMENTS are the simplest form of any substance known. These substances cannot be separated into simpler ones. For example it would be impossible to obtain anything from a sample of pure iron except iron.

COMPOUNDS (as referred to in this discussion) are a combination of two or more elements.

PLANTS. Of the eighty or more known elements only fourteen are commonly present in plants. These elements are rarely found free in nature but are generally found in combination with other elements. Water, protein, carbohydrates, and fats are the names of important compounds found in plants. Other compounds are also found in the ash (the residue left after burning).

WATER is composed of elements called hydrogen and oxygen and is a constituent of all plants. It makes up a large part of the gross weight of animals, being a part of all bone and flesh. The live body of a dairy cow, for example, is made up of water by about 56 per cent.

PROTEIN is a compound found in plants which contain nitrogen in addition to carbon, hydrogen, oxygen, phosphorus, and other elements. It is needed to make blood, muscle, internal organs, skin, hair, and milk. It is the compound which most concerns the dairyman since it is the most difficult nutrient to furnish through homegrown feeds. The total amount of protein is called crude protein, while that part of the protein which can be digested by the animal is called digestible crude protein. Not all feeds are equally digestible.

CARBOHYDRATES are compounds of carbon, hydrogen, and oxygen. They furnish energy for carrying on body functions and for keeping the body warm. Carbohydrates are easily supplied through the common farm feeds. The coarse, woody part of the carbohydrates is called crude fibre, while the rest is often called nitrogen-free extract. The crude fibre is not very digestible.

FAT is composed of carbon, hydrogen, and oxygen. It performs the same function in the animal body as carbohydrates but is 2¼ times as efficient.

TOTAL DIGESTIBLE NUTRIENTS are the digestible carbohydrates, plus the digestible protein, plus 2¼ times the digestible fat, which are found in the feed. They are the nutrients which can be used in the animal body, but converted in terms of carbohydrate.

FEEDS. All the feeds commonly fed to dairy cattle come from plants and are composed of the compounds water, protein, carbohydrates, fat, and ash or mineral matter.

ANIMAL BODY. The animal body is composed of the same compounds which are found in plants or feeds. It is therefore necessary to feed the right kinds and amounts of feed in order to maintain the animal body.

MILK. Milk also contains the same compounds (in different forms) found in feeds and in the body. It is not only necessary to furnish enough feeds for body maintenance. Such feeds also as contain the right amounts of protein, carbohydrates, fat, and mineral matter must be supplied for milk production.

The accompanying chart shows how the elements unite into compounds which form the feed out of which animals manufacture milk and derive their body needs (Figure 1).

The Right Amount of Feed

The dairy cow produces her milk from the feed and water which she consumes. Figure 1 shows how the elements unite into compounds to form the feed, out of which animals maintain their body needs and manufacture milk.

A cow must have food for maintenance, that is, to keep her body in running order, pumping blood, chewing and digesting food, mak-

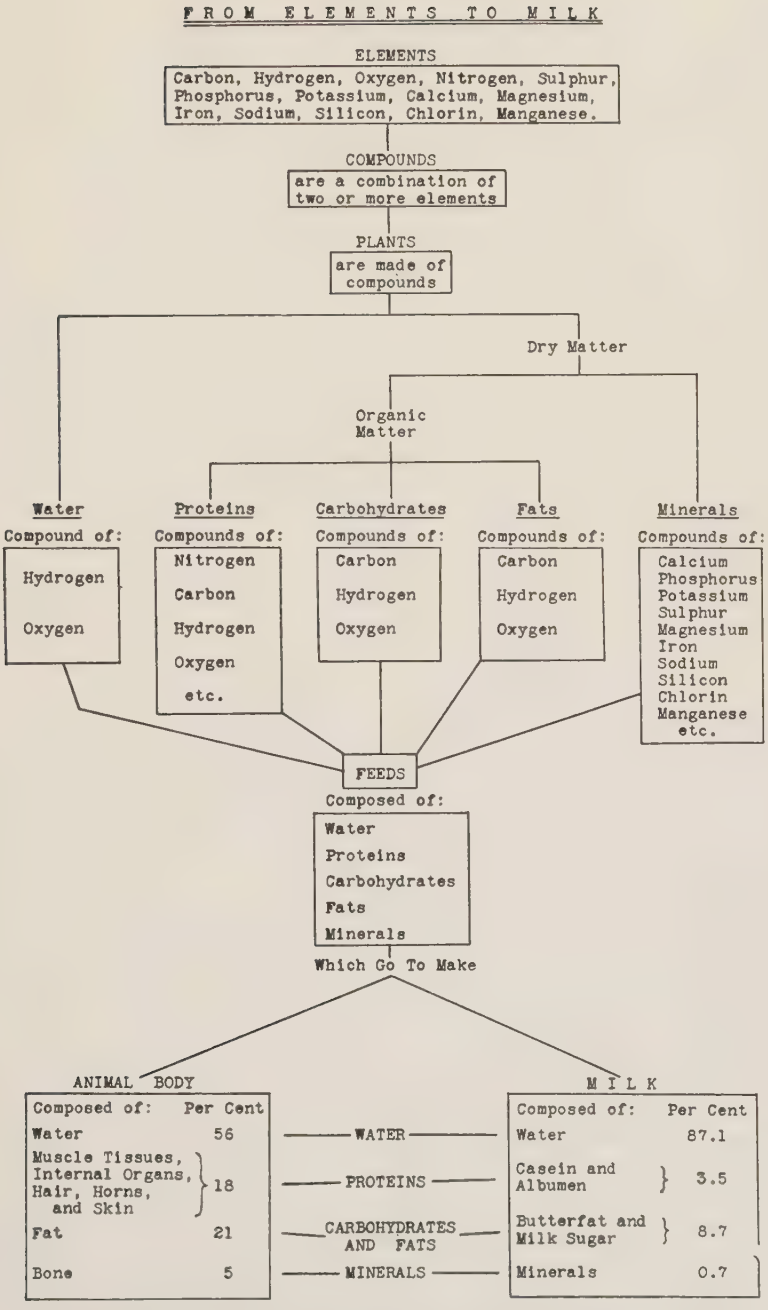


FIG. 1.—Interrelation of plant and animal life and the common component elements with their occurrence in various substances which go to make up feeds and, finally, milk

ing body repairs, etc. This maintenance requirement remains the same regardless of the milk production, and is determined by the size of the cow. After the maintenance requirement is fulfilled, a cow will produce milk according to her inherent ability and to the amount and kind of feed she receives. Figure 2 shows how the feed consumed by a dairy cow is utilized when she is given different amounts of feed.

WHAT BECOMES OF A COW'S FEED

When Fed Too Much—

Maintenance	Milk production	Gain in weight
1000-pound cow	20 pounds of 4% milk	stored up

When Fed Just Enough—

Maintenance	Milk production
1000-pound cow	20 pounds of 4% milk

When Fed Too Little—

Maintenance	Milk production
1000-pound cow	10 lbs. 4% milk

FIG. 2.—How the dairy cow utilizes her feed

This diagram shows that a cow when fed too much uses the excess feed to put on weight. When she is fed just enough she produces the maximum amount of milk, with no waste. And when she is fed too little, she loses first in milk, and later in weight, both of which are decidedly unprofitable to the owner.

A cow should be fed practically to the limit of her milk-producing capacity. In the case of the 1000-pound cow, producing 20 pounds of 4 percent milk, approximately 50 percent is used for maintenance and 50 percent for milk production. When, however, this cow produced only 10 pounds of 4 percent milk, largely because of lack of feed, approximately 67 percent of the feed was required for maintenance, leaving only 33 percent for milk production.

SOME COMMON FEEDS

Before one can feed the dairy cow most efficiently, one must know the characteristics of some of the more important dairy feeds. It is always best to feed as many home-grown feeds as possible and to buy only what may be necessary to balance them properly. In the following paragraphs are given some of the characteristics of the more important dairy feeds used in West Virginia.

Legume Roughages

ALFALFA. Alfalfa hay is one of the very best roughages for dairy cattle. It is very palatable and has a good effect upon the digestive system as it is slightly laxative in character. It is high in protein and is the highest in calcium of all the common feeds. Alfalfa has the added economic advantage that, while it can be produced at practically the same cost per ton as the other hays, its value as a dairy feed is much greater.

CLOVER. Clover hay has the same advantages as alfalfa hay, except that it is a little lower in protein and is slightly less palatable. Alsike, Crimson, and Red Clover have about the same feeding value, but Alsike is finer in the stem, which makes it especially well adapted for feeding young calves.

SOYBEANS. Soybean hay is fast becoming one of the most valuable crops raised by West Virginia dairymen. When properly cured, it makes one of the very best roughages for dairy cattle. It is slightly higher in protein and total digestible nutrients than is alfalfa. It is very palatable, but when allowed to get too ripe, has coarse, woody stems which the cows will refuse. It is slightly constipating in its effect, but is high in calcium.

Non-Legume Roughages

TIMOTHY HAY. Timothy hay is very low in protein and is not palatable except when harvested early. It is constipating in effect and low in its mineral content. Cows do much better when fed one of the legume hays than when fed timothy.

CORN STOVER. Corn stover (ears taken off) or "fodder," as it is incorrectly called, is one of the lowest protein roughages. It is not palatable, is constipating, and is low in minerals. It should be fed only in small quantities to dairy cows. Its feeding value is not improved by shredding.

STRAWS. Straw is a very poor feed for dairy cows, especially if the plant is allowed to become dead ripe. Oats straw is a little better than wheat straw or rye straw. All straws are low in protein and minerals, unpalatable, and constipating.

SILAGES. Corn silage is one of the cheapest and best roughages for dairy cows and is especially valuable because it offers the best means of supplying the necessary succulence during the winter. It is very palatable, and is laxative in its effect. Sunflower silage has been gaining in importance during the last few years. It is not as palatable as corn silage and does not seem to give quite as good results, although the yield of sunflower silage per acre is considerably greater, which makes it particularly well adapted to regions unadapted to corn or of limited tillable acreage.

ROOTS. Mangels, rutabagas, sugar beets, and turnips are fed to cows with good results. They are succulent in nature, laxative, and very palatable. The mangel is the most widely used and is unexcelled in adding succulence to the ration. It should be fed more generally, especially where there are too few animals to justify a silo or where the tillable acreage is limited.

Concentrates

CORN. Corn is grown on most West Virginia farms and should usually be included in the dairy ration. Cows like it and it supplies a large amount of total nutrients economically. It is low in protein and also in minerals. Therefore some high protein feed must be used in order to supply the lack of protein. It is best to feed corn ground as a meal. Sometimes whole ears are ground, making *corn-and-cob meal.* While cows do not like corn-and-cob meal quite as well as corn meal, it is often used to give bulk to the ration.

OATS. Oats is an excellent feed for dairy cattle. When not too high in price they should be used in the ration. They are considerably higher in food value than wheat bran. They are bulky, palatable, and fairly high in protein and mineral matter. If home-grown the straw comes in handy for bedding.

BARLEY. Barley is an excellent substitute for corn. It can be used in place of corn pound for pound, with equally good results. It contains a little more protein than corn, but is a little lower in total digestible nutrients.

BUCKWHEAT. Because of the large amount of fibre in the buckwheat hull, the whole grain is not so desirable for dairy cows as are the buckwheat middlings or bran of this grain. *Buckwheat middlings* are higher than wheat bran in feeding value and prove a very satisfactory feed for dairy cows.

WHEAT BRAN. Wheat bran is an excellent dairy feed. It is bulky and acts as a mild laxative. It also has a cooling effect, which makes it very useful as a feed for cows after calving. It is the highest of the common feeds in its phosphorus content. *Wheat middlings* or "shorts" are a very satisfactory feed for dairy cows, but are more like corn in composition and properties than bran. Middlings, if they can be purchased cheaper than corn, may be used as a substitute for corn in the ration.

GLUTEN FEED AND GLUTEN MEAL. Gluten meal is high in feeding value but is heavy and not very palatable. It should always be fed in a mixture with other feeds. It is a by-product of starch and glucose manufacture. When it is mixed with corn bran, it is known as *gluten feed,* which is now largely used as a dairy feed. It is often a cheap source of protein.

COTTONSEED MEAL. Cottonseed meal furnishes protein in the largest quantity and usually is the cheapest form of any of the common feeds. It is also high in minerals. It is somewhat constipating, however, and not very palatable; hence it should always be fed in combination with other feeds which will overcome these faults. It should never be fed in larger amounts than three or four pounds per day. Sometimes cottonseed hulls are ground and mixed with the meal and sold as cottonseed feed. This is considerably lower in feeding value than the meal.

LINSEED OILMEAL. Linseed oilmeal contains a high percentage of protein and is a very valuable feed. It is laxative, very palatable, and it has an excellent physiological effect on the digestive system of the cow. Because of these factors it is especially good when no succulent feed is used. It gives best results when fed with other grains and not in too large quantities. It is the residue after linseed oil is extracted from flax seed.

PEANUT MEAL. Peanut meal is becoming more important as a dairy feed. It is a by-product of the manufacture of peanut oil. It varies considerably in composition, but high-grade peanut meal is very high in protein, is palatable, and has a slightly laxative effect upon the cow.

DRIED BEET PULP. Dried beet pulp is very high in carbohydrates, but low in protein. When silage or other succulent feeds are not available, dried beet pulp makes an excellent substitute when soaked with water for about twelve hours before feeding. It is very palatable, and has a very good physiological effect upon the cow.

MOLASSES. Molasses is not usually fed for its food value, as it contains practically no protein; and for its total nutrients it is not an economical feed. Its chief value is as an appetizer, for when sprinkled over unpalatable feeds it lends palatability to them. Molasses is quite laxative and cannot be fed in large quantities. It is often used when cows are on official test in order to have the cows consume more feed.

Ready-Mixed Feeds

A large number of ready-mixed dairy feeds are now being sold in West Virginia. They have the advantage of supplying the necessary variety to a ration and being ready-mixed they save the labor of mixing. In the past, these ready-mixed feeds were not looked upon with favor because many of them were sold simply as a means of disposing of some inferior products. Laws have since been passed and are now in force, requiring the labeling of each sack with a guaranteed analysis and with a list of ingredients contained in the feed. The law also forbids the use of inferior products. At the present time many excellent ready-mixed feeds are to be found on the market. *Open formula* feeds have the advantage that they show on the

sacks the feeds and the amount of each which has been used in the ration. They have been gaining in popularity very rapidly.

Ready-mixed feeds are of special value to the dairyman who uses only a small amount of feed or who is so located that it is impossible to obtain readily a variety of feeds for home mixing. The buyer should always pay close attention to the guaranteed analysis, so that he may get his protein and total nutrients as cheaply as possible. His decision as to the use of ready-mixed feeds should depend largely upon the relative price. If the dairyman, however, has on his farm corn, barley, or oats, and needs a high protein feed to balance these, as a rule he can purchase his protein cheaper in the form of cottonseed meal, linseed oilmeal, or gluten feed. It is always best to figure the cost of a pound of protein from each before purchasing, and in that way be sure of purchasing the most economical ration.

DESIRABLE CHARACTERISTICS OF A RATION

In the making of a dairy ration it should be the aim as nearly as possible to imitate early summer pasture conditions. Every dairyman knows that the period of highest and most economical milk production is during the early summer months. The reason for this is not hard to find. Early summer pasture provides for the dairy cow an *abundance* of *palatable* feed which is *succulent* in nature. It also has plenty of *bulk* and *variety* and it has a *good physiological effect* upon the cow. Pasture also is *cheap*. These characteristics of pasture are the things which a good feeder tries to imitate throughout the year.

ABUNDANCE OF FEED. Plenty of feed is the first essential in feeding cows for profit. The cow should be looked upon as a factory, and as in any other factory, the cheapest production is possible only when the plant is being run nearly to its full capacity. The most common mistake in feeding dairy cows is the failure to give enough feed to make full use of the milk-producing ability of the cows. Cows should be fed as individuals, that is, in proportion to the milk which they are producing. There is no profit in a herd of half-starved cows.

PALATABLE FEED. A feed to be palatable must be pleasing in flavor so that cows like it. A cow will do her best when she relishes her feed. A ration may contain everything necessary for maximum production, yet if it is not palatable, the cow may not consume enough for it for her maximum production. We want to tempt the cow's appetite and induce her to eat feed up to the limit of her ability for production. Early spring pasture is a very palatable feed. Pasture in late summer is much less palatable, which is one reason why the cows drop off so rapidly at that time.

SUCCULENT FEED. A succulent feed is one which contains the juices of green forages similar to the natural juices of pasture grass. These juices stimulate the production of milk, and a maximum flow of milk is difficult without them.

BULK. Pasture is bulky. Likewise any good ration should be bulky to enable the digestive juices to penetrate the food most completely and thereby facilitate digestion.

VARIETY. It is well to add variety to a ration. If the feed is obtained from only one plant, it is very likely that some of the essentials for maximum milk production will be omitted. It is well to have two, or better three, different plants represented in the grain ration. This will help furnish the special forms of protein required by a cow in milk and also the needed mineral matter. Variety is especially important when large records are being attempted.

PHYSIOLOGICAL EFFECT. Each feed has its own specific effect upon the cow's body. The effects of certain feeds are very pronounced. The bowels of the dairy cow should be in slightly laxative condition if she is to make her best production. Fresh pasture is laxative in nature. When roughages are constipating in effect, the grain ration should be of a laxative nature.

CHEAP. Good pasture not only is a good feed but it is a cheap feed. The careful feeder will also try to select cheap feeds but in this he will not make the cost price per ton the essential consideration. The important thing which should be considered is the cost of one pound of protein or one pound of total nutrients.

BALANCING RATIONS FOR A DAIRY HERD

A balanced ration is one that exactly meets the daily needs of a dairy cow, both for the maintenance of her body and for the production of milk. Feeds are divided into two general groups: roughages and concentrates. Roughages are cheaper, and so cows should be fed all that they will clean up. They usually, however, cannot eat enough roughage to supply the required food nutrients for both maintenance and milk production. They must therefore be fed grain in addition to the roughage. The concentrates are used to balance the roughage fed; hence the kind of concentrates or grain mixture needed will depend upon the class of roughage fed. The different kinds of roughage fall into three general classes based on their protein content.

The roughages commonly fed to dairy cows can be grouped in three classes: low protein, medium protein, and high protein. When the roughages are fed liberally all that the cows will clean up, the percentage of protein in the grain mixture to feed with the different roughages is as follows:

1. LOW PROTEIN GROUP. Timothy hay, corn stover, silage, or any other non-legume.

Crude protein 24% *or digestible protein* 18-21%.

2. MEDIUM PROTEIN GROUP. Mixed hay, clover and silage, or other roughages, with at least half of the roughage legume.

Crude protein 20% *or digestible protein* 14-17%.

3. HIGH PROTEIN GROUP. Alfalfa hay, soybean hay, clover hay, or any of the legume roughages fed as the sole roughage.

Crude protein 16% *or digestible protein* 10-14%.

The grain mixture should always be balanced with the roughage fed.

Practice in Making Grain Mixtures

For general farm use, it is not always practical to balance exactly the amounts of protein, fats, and carbohydrates needed. Since there is seldom a deficiency in carbohydrates and fats, when the cow has all the roughages that she can eat, a roughly balanced ration may be obtained by balancing the protein of the grain mixture to go with the kind of roughage as already indicated under the three groups of roughages, and disregarding the carbohydrates and fat.

As an example of this method of making up a ration for a dairy herd, let us assume that we have on hand alfalfa hay and corn silage for roughage, which is the medium protein group, and that we have available corn meal, ground oats, wheat bran, and cottonseed meal. By referring to Table 2 we get the following figures for protein:

100 pounds cornmeal contains _____ 7.1 pounds digestible protein
100 pounds wheat bran contains ____12.5 pounds digestible protein
100 pounds ground oats contains ___ 9.7 pounds digestible protein
100 pounds cottonseed meal contains 37.0 pounds digestible protein

400 pounds of the mixture contains__66.3 pounds digestible protein
66.3 divided by 400 equals .166, or 16.6 percent digestible protein.

By referring to the Groups of Roughages, it will be noted that when the roughage is in the medium protein group, the percentage of protein in the grain mixture should be from 14 to 17 percent. This ration, then, should fulfill the needs, provided, of course, it fulfils the requirements as to bulk, variety, palatability, physiological effect, mineral content, etc. This ration should fulfill these requirements.

Now let us assume that instead of alfalfa and silage for roughage we have only timothy hay and corn stover, which are in the low protein group, with the same concentrates as before. It would be necessary then to add more of the high protein feeds as follows:

400 pounds of the mixture contains____66.3 pounds digestible protein
100 lbs. cottonseed meal contains____37.0 pounds digestible protein

500 lbs. of the new mixture contains___103.3 pounds digestible protein
103.3 divided by 500 equals .2066, or 20.7 percent digestible protein.

By referring to the Groups of Roughages, it will be noted that when the roughage is in the low protein group, the digestible protein in the grain mixture should be from 18 to 21 percent. This ration fills these requirements and therefore should be a good ration under the given conditions.

Now suppose that the roughage consisted of alfalfa hay, which is in the high protein roughage group, and that the same concentrates were available. It would be necessary to add a low protein concentrate like corn, as follows:

400 pounds of the mixture contains---66.3 pounds digestible protein.
150 pounds corn meal contains------10.7 pounds digestible protein.
550 pounds of new mixture contains--77.0 pounds digestible protein
77.0 divided by 550 equals .140, or 14.0 percent digestible protein.

We note that the grain mixture in the high protein group should be between 10 and 14 percent and hence the above ration would fill the requirements but could be still a little lower in protein, if desirable for any reason.

Any of the foregoing rations would be suitable for the conditions given, provided they were fed in proportion to the amount of milk that the cows produced; that is, one pound of grain to each three or four pounds of milk that the cow produces, as pointed out in the general rules for feeding dairy cows on page 2.

It is fairly easy to balance a grain mixture in this way for any kind of roughage. If the roughage is low grade, use a higher protein percentage in the grain mixture, and vice versa. It is important, however, to keep in mind the characterisics of the feeds when making up the grain ration and always to feed the ration according to production.

It is also well to consider the cost of the protein in the feeds used to make up the ration and always to take the least expensive, everything else being equal. This can easily be ascertained by the use of the cost co-efficients for getting cost of digestible protein and total nutrients as given in Table 2.

Fit Crops to Ration

The best rations for dairy cows include legume hays. Not only are they more palatable than the other roughages but they also cheapen the cost of the ration. Legume hays can be grown on most West Virginia farms and the efficient dairyman always grows enough for the needs of his dairy herd.

Substitutions

If one has a ration already worked out for his herd, it is very handy sometimes to make certain substitutions.

In a ration, any of the following feeds can be interchanged as indicated without seriously affecting the food value of the ration:

1. Oats for wheat bran and vice versa.
2. Ground barley for corn meal and vice versa.
3. Corn-and-cob meal for corn meal and vice versa.
4. Hominy for corn meal and vice versa.
5. Cocoanut meal for gluten feed and vice versa.
6. Buckwheat middlings for gluten feed and vice versa.
7. Linseed oilmeal for cottonseed meal and vice versa.

Good Grain Mixtures with Different Roughages

A series of grain mixtures suitable to West Virginia conditions is given here for convenience.

FOR LOW PROTEIN ROUGHAGES

(Digestible protein in grain mixture 18 to 22%.)

No. 1.—Digestible Protein 18.9%
200 pounds wheat middlings
100 pounds corn-and-cob meal
100 pounds cottonseed meal
50 pounds linseed oilmeal

No. 2.—Digestible Protein 20%
100 pounds corn meal
100 pounds cottonseed meal
100 pounds linseed oilmeal
200 pounds wheat bran

No. 3.—Digestible Protein 20.6%
100 pounds corn meal
100 pounds cottonseed meal
100 pounds gluten feed
50 pounds wheat bran

No. 4.—Digestible Protein 20.5%
400 pounds ground barley
400 pounds gluten feed
400 pounds cottonseed meal
100 pounds linseed oilmeal

No. 5.—Digestible Protein 19.1%
100 pounds corn-and-cob meal
100 pounds ground oats
200 pounds cottonseed meal
200 pounds wheat bran

FOR MEDIUM PROTEIN ROUGHAGES

(Digestible protein in grain mixture 15 to 18%.)

No. 6.—Digestible Protein 15.0%
100 pounds corn meal
100 pounds wheat bran
100 pounds ground oats
100 pounds linseed oilmeal

No. 7.—Digestible Protein 17.3%
300 pounds corn meal
100 pounds cottonseed meal
200 pounds buckwheat middlings
100 pounds wheat bran

No. 8.—Digestible Protein 16.8%
200 pounds corn meal
150 pounds cottonseed meal
100 pounds ground oats
100 pounds wheat bran

No. 9.—Digestible Protein 16.3%
100 pounds corn-and-cob meal
100 pounds cottonseed meal
100 pounds ground oats
100 pounds wheat bran

No. 10.—Digestible Protein 15.7%
200 pounds ground corn
200 pounds ground oats
200 pounds wheat bran
400 pounds linseed oilmeal

FOR HIGH PROTEIN ROUGHAGES

(Digestible protein in grain mixture 12 to 15%.)

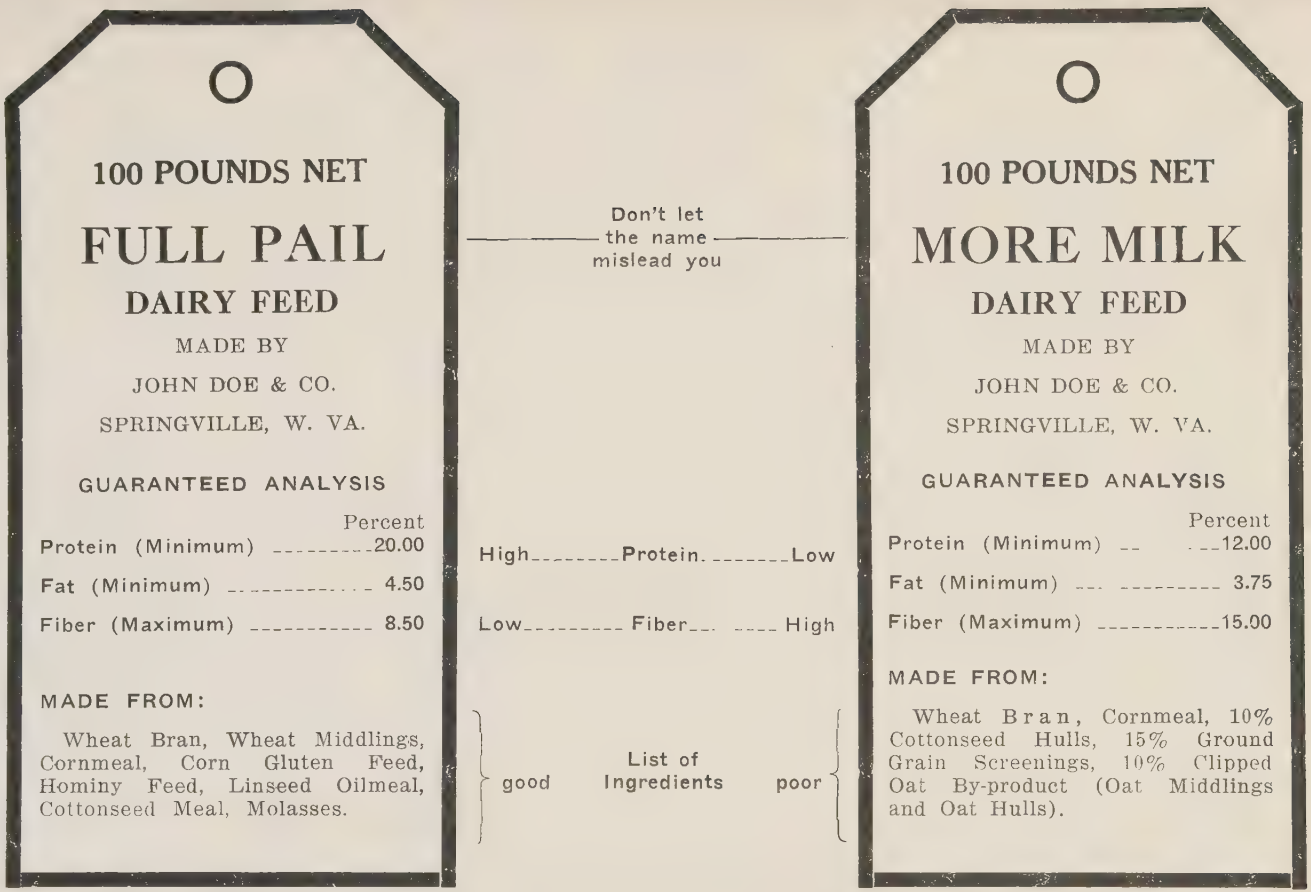
No. 11.—Digestible Protein 12.3%
200 pounds corn meal
100 pounds ground oats
100 pounds wheat bran
100 pounds buckwheat middlings

No. 12.—Digestible Protein 12.2%
200 pounds corn meal
100 pounds gluten feed
100 pounds wheat bran

No. 13.—Digestible Protein 13.3%
200 pounds corn meal
100 pounds ground oats
100 pounds wheat bran
100 pounds linseed oilmeal

No. 14.—Digestible Protein 14.1%
400 pounds corn meal
100 pounds cottonseed meal
100 pounds wheat bran
100 pounds gluten feed

No. 15.—Digestible Protein 14.4%
300 pounds ground corn
100 pounds wheat bran
100 pounds cottonseed meal



Study the Feed Tag—It Tells the Story

Balancing Rations Accurately

Sometimes it is desirable to balance a ration for a herd or for an individual cow more accurately than the protein requirement gives it. Table 1 gives the daily requirements for dairy cows according to the Morrison Feeding Standard.

TABLE 1.—*Daily Requirements for Dairy Cows*

Maintenance and Production	Digestible Crude Protein in Pounds*	Total Digestible Nutrients in Pounds*
Maintenance for 1000-pound cow	0.700	7.925
Maintenance for each 100 pounds live weight	0.070	0.7925
For 1 pound of 3 % milk	0.052	0.271
For 1 pound of 3.5% milk	0.055	0.300
For 1 pound of 4 % milk	0.059	0.328
For 1 pound of 4.5% milk	0.063	0.357
For 1 pound of 5 % milk	0.066	0.382
For 1 pound of 5.5% milk	0.070	0.406
For 1 pound of 6 % milk	0.074	0.431

*Computed from **Feeds and Feeding**, Henry and Morrison.

It will be seen from Table 1 that a 1250-pound cow will require for maintenance 0.875 pounds of digestible protein and 9.906 pounds of total digestible nutrients. However, if this cow is producing 24 pounds of 3.5% milk, she will require in addition, according to the table, 1.32 pounds of digestible protein and 7.20 pounds of total digestible nutrients. Her total requirements, therefore, would be 2.195 pounds of digestible protein and 17.106 pounds of total digestible nutrients, which total we get by adding together the maintenance requirement and the milk requirement, thus:

Maintenance and Production	*Digestible Crude Protein in Pounds*	*Total Digestible Nutrients in Pounds*
Maintenance for 1250-pound cow ----	0.875	9.906
Production of 24 pounds of 3.5% milk--	1.320	7.200
Total requirements ----------	2.195	17.106

Having found out exactly what it takes to maintain a cow of this size, giving the quantity of milk mentioned, the problem then is how to select the right feeds in the correct proportion in order to meet these requirements.

The following ration very closely gives the total requirements:

Feeds	*Total Crude Protein in Pounds*	*Total Digestible Nutrients in Pounds*
10 pounds alfalfa hay ----------	.650	)
35 pounds corn silage ----------	0.385	6.195
5 pounds corn meal ----------		
2 pounds ground oats ----------	0.194	1.408
½ pound cottonseed meal ----------	0.185	0.391
Total ----------	2.179	17.239

By the same method a ration for any cow can be worked out when her requirements based on her approximate weight, her milk production, and percentage of butterfat are known. The average requirements of a herd can also be used in computing a ration for a herd as a whole.

Feeding Cows On Pasture

The problem of feeding cows on pasture is frequently overlooked by dairymen. The beginning of the pasture is awaited with impatience. Often this impatience overcomes good judgment and the cows are turned on pasture too early in the spring. When this is done it generally decreases the yield of grass throughout the rest of the summer. Since much of the food of the grass plant is manufactured in the leaves or blades, if the cows are allowed to graze while the grass is very short, its growth will be slow. The early grasses are mostly water, and heavy milking cows cannot eat enough immature grass to supply them with the necessary nutrients. Hence it is a good practice to continue feeding the cows some hay, silage, and grain for a time after they are turned on pasture.

Experience has proved that even good pasture will not furnish enough food for the high-producing cow. Grasses contain a large amount of water and are bulky, which makes it impossible for heavy producers to consume enough to keep up production.

The best abundant pasture will furnish only enough nutrients for cows which are producing not more than 20 pounds of milk per day. A guide for feeding grain to cows on pasture is as follows:

For Jersey or Guernsey cows producing

25 pounds of milk daily	feed 1 pound of grain to each 6	pounds of milk
30 pounds of milk daily	feed 1 pound of grain to each 5	pounds of milk
35 pounds of milk daily	feed 1 pound of grain to each 4½	pounds of milk
40 pounds of milk daily	feed 1 pound of grain to each 4	pounds of milk

For Holstein, Ayrshire, Brown Swiss, or Shorthorn cows producing

25 pounds of milk daily	feed 1 pound of grain to each 7	pounds of milk
30 pounds of milk daily	feed 1 pound of grain to each 6	pounds of milk
35 pounds of milk daily	feed 1 pound of grain to each 5½	pounds of milk
40 pounds of milk daily	feed 1 pound of grain to each 4	pounds of milk

In feeding grain to cows on abundant pasture the grain mixture can be made up of relatively small amounts of the high-protein concentrates. The following grain mixtures have proved to be satisfactory:

No. 1.—Digestible Protein 12.7%
100 pounds corn meal
100 pounds wheat bran
25 pounds cottonseed meal

No. 2.—Digestible Protein 11.3%
400 pounds corn meal
100 pounds cottonseed meal
100 pounds ground oats
100 pounds wheat bran

No. 3.—Digestible Protein 10.4%
100 pounds wheat bran
100 pounds ground oats
50 pounds corn meal

As late summer approaches, the need for pasture supplement generally becomes more acute and the grain mixture at this time should be richer in protein. During this period the pastures generally become short from dry weather. Silage has proved to be the best forage supplement for pasture, although soiling crops such as green corn, oats, or soybeans may be used if the land and labor are available. It pays to supplement these feeds with one of the above grain mixtures and hay, if necessary, in order to keep up the production of heavy milking cows.

OTHER CONSIDERATIONS

COMMON SALT. It has always been known that cattle have a craving for common salt and that to deprive them of this substance will end in disastrous results. They will gradually lose vitality, their hair will become rough, they will become thin in flesh and finally will have a complete breakdown. It is necessary, therefore, to supply dairy cattle with plenty of salt.

One of the most common ways of supplying salt is to keep it so that the animals will have free access to it and will take what they require. It may also be supplied in part by mixing it with the grain ration in the proportion of 1 to 1¼ pounds of salt for each 100 pounds of grain mixture. The practice of salting only at intervals of certain periods is not to be recommended. The amount actually needed is about ¾ of an ounce daily for each 100 pounds of live weight and ½ ounce in addition for each 20 pounds of milk produced.

CALCIUM AND PHOSPHORUS. The importance of calcium and phosphorus in the dairy ration has been somewhat over-estimated. Under West Virginia conditions, if the dairy cows are given plenty of legume hay in winter and pasture in summer, and are fed a good grain ration, there is little to be feared from lack of these elements. Legume hays are the best source of calcium, while concentrates like wheat bran and cottonseed meal are the best sources of phosphorus.

If, however, cows show abnormal appetites such as a craving for wood, bones, or dirt, there is a strong indication that the ration is lacking in one or both of these elements. This is more likely to be true with the heavy producers or when the roughage is timothy or other non-legume hay. In either of these cases it is usually advisable to supply some of these elements, for while the cow may not show any definite signs, nevertheless she is drawing upon her body reserve, which must later be replenished.

When it is found advisable to supply these elements in some form other than that supplied by the feeds being used, it is usually recommended to feed some bonemeal, of the kind especially prepared for livestock feeding. This contains both calcium and phosphorus in the proportions used in the body. It is sold by the large packing

houses under the name of "raw bonemeal for feeding." Spent bone black serves the same purpose as the bonemeal and sometimes can be purchased at a lower price. Ground limestone or wood ashes may also be used but they supply only the calcium. In case ground limestone is used, only limestone which is low in magnesium should be used.

Many commercial mineral compounds are on the market, but no better results can be expected from them than from bonemeal or from a mixture of bonemeal and limestone. The price of commercial preparations is usually much higher that that of the bonemeal.

The bonemeal, ground limestone, or wood ashes can be fed like salt by allowing free access to it, or it may be added to the grain ration at the rate of about 2 pounds to each 100 pounds of the ration.

WATER. Since milk is 87 percent water, it is obvious that dairy cows should receive all the water they can drink. A large cow milking heavily will drink as much as 100 pounds (8 to 10 gallons) of water in a day. When closely stabled, cows should be watered at least twice a day, or better still, have water where they can get it when they want it. In cold weather the water ought to be at least 20 degrees above freezing.

The master's eye is careful to weigh the feed

TABLE 2.—*Average Amount of Digestible Protein and Total Nutrients in 100 Pounds of Common Feeds**

Feeds	Pounds Digestible Crude Protein	Pounds Total Digestible Nutrients	Cost Coefficient†	
			Protein	Total Nutrients
GRAINS				
Cornmeal	7.1	81.7	14.08	1.224
Corn-and-cob meal	6.1	78.1	16.39	1.280
Oats	9.7	70.4	10.31	1.424
Barley	9.0	79.4	11.11	1.259
Buckwheat	8.1	63.4	12.34	1.574
Soybeans	33.2	94.1	3.01	1.061
Cowpeas	19.4	76.4	5.15	1.309
Rye	9.9	81.0	10.10	1.234
BY-PRODUCTS				
Cottonseed meal (choice)	37.0	78.2	2.70	1.278
Cottonseed meal (prime)	33.4	75.5	2.99	1.324
Linseed oilmeal (old process)	30.2	77.9	3.31	1.284
Linseed oilmeal (new process)	31.7	75.9	3.15	1.317
Gluten feed	21.6	80.7	4.63	1.238
Gluten meal	30.2	84.0	3.31	1.190
Wheat bran	12.5	60.9	8.00	1.642
Wheat middlings	13.4	69.3	7.46	1.443
Wheat middlings (flour)	15.7	78.2	6.37	1.278
Buckwheat middlings	24.6	76.6	4.07	1.305
Corn bran	5.8	73.1	17.24	1.368
Hominy feed	7.0	84.6	14.29	1.182
Cocoanut meal (old process)	18.6	78.8	5.32	1.269
Soybean oilmeal	39.7	84.5	2.51	1.183
Sugarbeet pulp (dried)	4.6	71.6	21.74	1.396
Distiller's grain from corn (dried)	22.4	88.9	4.46	1.124
Malt sprouts	20.3	70.6	4.92	1.416
Molasses (beet)	2.9	58.7	34.48	1.703
Molasses (cane)	1.0	59.5	100.00	1.681
Alfalfa meal	10.2	50.7	9.80	1.972
DRIED ROUGHAGES				
Alfalfa hay	10.6	51.6	9.43	1.938
Soybean hay	11.7	53.6	8.55	1.865
Clover (red)	7.6	50.9	13.16	1.964
Clover (alsike)	7.9	47.3	12.67	2.114
Clover (crimson)	9.7	48.7	10.31	2.053
Clover (sweet)	10.0	47.0	10.00	2.149
Cowpeas	13.1	49.0	7.63	2.041
Mixed timothy and clover	4.0	46.2	25.00	2.164
Timothy	3.0	48.5	33.33	2.061
Corn fodder medium in water (ears included)	3.0	53.7	33.33	1.866
Corn stover (ears removed)	2.2	52.2	45.45	1.911
Millet (Hungarian)	5.0	55.0	20.00	1.818
Oat hay	4.5	46.4	22.22	2.155
Oat straw	1.0	45.6	100.00	2.193
Buckwheat straw	4.2	33.2	23.81	3.012
Wheat straw	0.7	36.9	142.86	2.172
SILAGE AND ROOTS				
Corn silage (matured)	1.1	17.7	90.00	5.649
Sunflower silage	1.0	12.6	100.00	7.936
Clover silage	2.0	13.4	50.00	7.462
Soybean silage	2.8	15.6	35.71	6.410
Beets (common)	0.9	10.2	111.11	9.803
Beets (sugar)	1.2	14.0	83.83	7.142
Turnips	1.0	7.4	100.00	13.513
Mangels	0.8	7.4	125.00	13.513
Pumpkins (field)	1.1	6.7	99.99	14.924
Rutabagas	1.0	9.4	100.00	10.637

†To get the cost of 100 pounds of Protein and Total Nutrients in feeds, multiply the cost coefficient by the cost per hundred pounds of feed.

*Analyses from Henry and Morrison, **Feeds and Feeding**, 18th Edition.

Circular 57
ARIZ.UNIV.LIB. JAN 23 1931
November, 1930

Topworking the Apple Tree

by M. B. HOFFMAN

Scaffold Limbs of Young Topworked Tree. Lines Show Location of Grafts

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

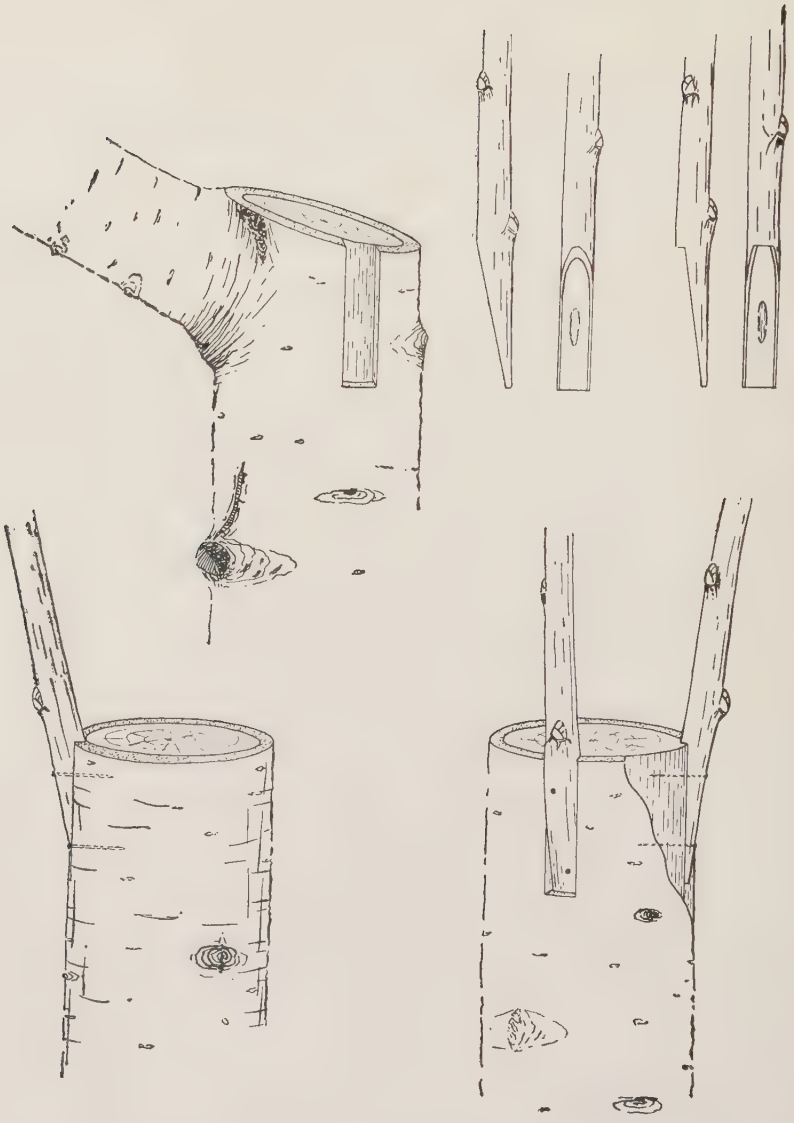


FIG. 15.—The top drawing shows how a bark graft may be used to heal a wound when a large limb is cut back to a side branch. The cion should be set at the heel of the cut, directly opposite the side branch. Cions for bark grafting may be made with a plane bevel or a shoulder as shown above. Do not use this graft for regular topworking, because the cions blow out too easily

Topworking the Apple Tree

by M. B. HOFFMAN

MANY ACRES of apple orchards in West Virginia are set in large blocks consisting of a single variety. Experiments have shown that many of these varieties are wholly or partially self-sterile. Examples are Stayman, Arkansas (Mammoth Black Twig), Winesap, and Delicious. This means that yields are and will continue to be very unprofitable unless pollen from another suitable variety is supplied to these blocks. The logical thing to do in such cases is to topwork about one tree in every 25 to a variety that will fertilize the variety in question. Grimes Golden has been found to be an excellent pollenizer for Stayman. Therefore, for the orchardist who is experiencing light yield from Stayman, it is usually recommended that every fifth tree in every fifth row be topworked to Grimes or some other variety which experience has shown to be compatible. Arkansas (Mammoth Black Twig) will set fruit, other things being favorable, when supplied with either Jonathan or Delicious pollen, but Grimes will not fertilize it. A partially self-sterile variety, such as Delicious, would show increased sets of fruit if a few trees in the orchard were topworked to Grimes.

Bees are necessary for carrying pollen from the flowers of the topworked trees to flowers of the sterile variety. It takes three or four years' growth of the top of the newly-grafted tree before any blossoms will appear. During this time pollen may be supplied to an orchard such as Stayman, by taking blossoming branches of Grimes into the orchard and placing them in pails of water near bee hives. The bees will visit these Grimes Golden blossoms and there pick up quantities of pollen which they will later carry to blossoms on the Stayman trees. When Grimes flowers begin to form on the topworked trees, this will be unnecessary. But it is still important that a hive of bees be kept at or near the trees top-worked to Grimes.

Unknowingly, trees are sometimes sold which are not true to name. This may not be discovered until they have come into bearing. The variety may be one that is known to be a total failure in that region, or it may not be suited to the market at hand. Growers sometimes order new varieties that are not fully tested only to find them undesirable or unsuited to their location. In all such cases, topworking of these trees to more desirable varieties may prove neces-

ACKNOWLEDGMENT

The writer is indebted to the Department of Horticulture, Michigan Agricultural Experiment Station, for the use of Figures 6, 8, 9, 10, 11, 12, 13, 14, 15, 19, 20, 21, and 22; and to the Department of Horticulture, Maryland Agricultural Experiment Station, for the use of Figures 2, 3, 4, and 5. Mr. P. S. Flegel made the drawings for Figures 1, 7, and 24.

sary. It is the purpose of this circular to discuss a few of the methods of top-working established by experience as most likely to be successful under average conditions.

Explanation of Terms

Top-working means the grafting or budding of a new top of a different variety on the trunk or branches of a tree. The practice is thus distinguished from grafting or budding near the ground as followed in nursery practice.

Stock refers to the root, trunk, or limbs into which the graft is made. The stock usually furnishes the root system of the tree, but it may furnish a part of the top, particularly the frame work of the top-worked tree. Stocks for root systems are usually grown from seed.

The term stub is used to designate that portion of a limb that is left after sawing off the limb for the purpose of grafting. The stub is that part of the stock on which the graft is made.

Cion signifies the twig that is grafted into the stock. It later becomes the limb or tree and furnishes all the fruiting area.

The bud in budding plays the same role as the cion in grafting. The bud consists of a leaf bud adhering to a small piece of bark, all of which is inserted on the stock. Grafting and budding differ in method and season, but both are based on the same underlying principle.

Cambium layer refers to a layer of living cells that completely surrounds all the woody portions of the tree. The layer is not over six to ten cells in thickness; therefore it is hardly discernible with the unaided eye. The location of the cambium can be recognized by pulling off some bark from the tree while the bark is loose. This splits the cambium cells; part of them adhere to the wood and part to the bark. The paste-like shiny material that can then be scraped from the wood or inside of the bark contains a great many cambium cells. During the growing season the cells of this cambium layer are constantly dividing, forming new cells. Those cells formed on the inside of the layer differentiate into the woody portion of the stem while those formed on the outside of this layer form the inner bark. The cambium layer is the source of all growth in so far as increase in diameter of woody stems is concerned. It is also responsible for most callus formation, particularly in older limbs. The importance of callus formation in the healing of wounds and "the take" of grafts is evident. The cambium layer is one of the most active tissues in woody stems and its preservation is essential to further growth.

Season for Top-working

The best time to top-work a tree is when the buds begin to swell in early spring. At this time the growth processes are becoming more active and the bark is still rather tight. This may be considered an advantage in making the cleft graft, since the bark and wood of the

FIG. 1.—At the left is a piece of poor cion wood. The past season's growth was poor and is confined to the one-half inch near the tip. The remainder of the twig is 2-year-old wood. The buds on it are not lateral buds but small non-vigorous spurs. The center drawing represents good vigorous cion wood. All of the growth was made the past season and the buds are well developed. The drawing at the right is 1-year-old wood, but the buds are too poorly developed to make good cion wood. Never use 2-year-old wood or 1-year-old wood with poorly developed buds

stock will split along the same line. If the bark is slipping easily it may split to one side of the wood and cause difficulty in the proper setting of the cion. Both the cleft graft and the whip or tongue graft can be made while the stocks and cions are still dormant. Grafting may be continued up until the trees are in bloom, provided dormant cions are used, but greatest success is usually obtained if the work is done when the buds are swelling.

Collecting Cion Wood

Cion wood should always be cut while dormant and kept in this condition until it is grafted. If the wood is collected during the late fall or early winter, it should be carefully wrapped in cloth or heavy paper and buried in a horizontal position on a well-drained spot. Burying it below the frost line and deep enough to keep it from drying out will insure success. Since there is little danger of winter injury to the wood of apple trees in West Virginia, it is just as well that the collection of cion wood be delayed until early spring. Enough material should be collected at one time to give a plentiful supply of good cion wood for all the grafting that is to be done. This wood should be stored immediately and taken from storage as needed. The main requirements of storage are that it be cool enough to prevent growth, with a humidity high enough to keep the wood from drying out. There is no better method of handling than that of burying in the ground as previously described. Thorough wrapping of cions will keep soil from clinging to the wood. Soil particles on the cion are objectionable because they may ruin the edge of the grafting knife.

Cions should be cut from wood of the previous season's growth; that is, cions set in the spring of 1931 should be cut from wood that

grew in 1930. This wood is easily distinguished from the 1929 wood by the ring of bud scars that circle the twig where the two growths meet. This ring of scars shows the location of the 1929 terminal bud and marks the beginning of 1930 growth. Wood older than the previous season's growth should not be used in commercial top-working.

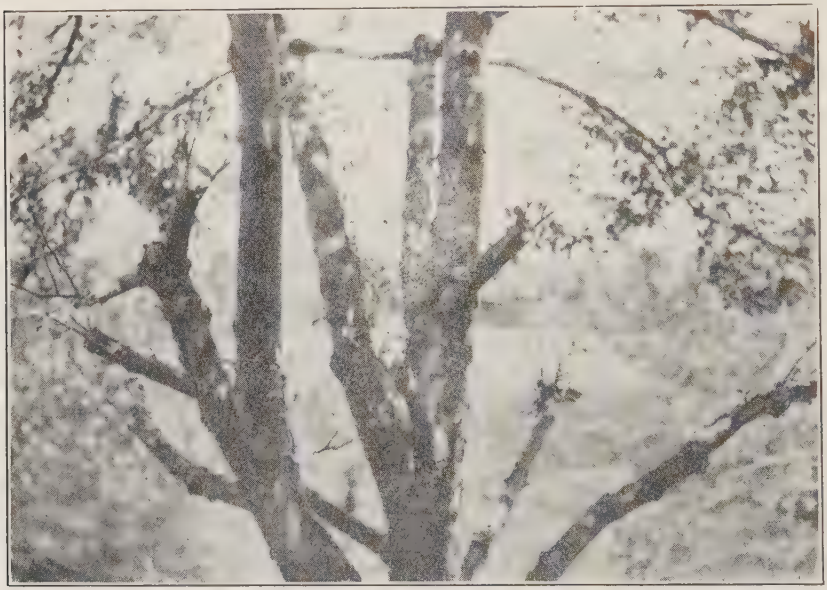


Fig. 2.—These cions have made a very weak growth because of too much shade. More of the tree top should have been removed so that the cions might have received full benefit of all the sunlight

The Michigan Station has succeeded in getting cions to grow that were taken from three-year old wood, but the percentage of "take" was low.

The best cions can usually be cut from wood that made a growth of one to two feet during the last season. Growth of about lead pencil diameter is desirable. Experimental work in Illinois has very definitely shown that there is no advantage in selecting cion wood from any particular part of the tree. Very good cion wood may be cut from water sprouts provided the water sprouts originate on the tree trunk above the graft and the buds on them are well developed. Very often a twig has poorly developed buds at the base and near the top. Such sections should be discarded and only the middle portion of the twig cut into cions.

Selection of Limbs for Top-working

When selecting limbs to top-work, several things should be kept in mind. A limb between one and two inches in diameter is the most

desirable size to top-work. Limbs smaller than an inch in diameter will require special attention after the graft is made or may even require a method of grafting different from the one ordinarily employed. Though it is not recommended, it is sometimes necessary to graft limbs larger than two inches in diameter; especially is this true in the case of old trees where a few must be top-worked for pollination purposes. Reasonably good success will accompany the

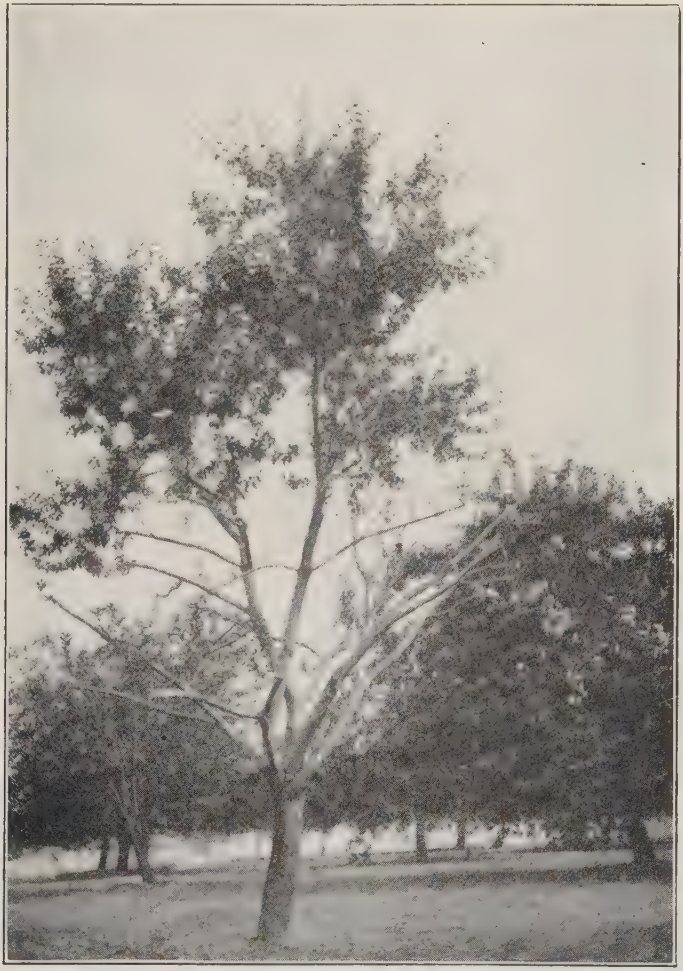


FIG. 3.—Improper placing of grafts. Never set grafts out at the ends of long limbs. Compare with FIG. 4

grafting of limbs three and four inches in diameter if ideal light is present and good care is given the cions. Another scheme that may help in the grafting of larger limbs is to make two parallel clefts, one

on each side of the center of the stub, and set two cions in each. (This will be made clearer after the technique of cleft grafting is explained.)

Excessive shading of the graft results in weak growth of the cion. This is shown in Figure 2. Grafts should be made only in the places where they can be expected to develop into large limbs. It is easy and convenient to graft the small horizontal limbs that are close to the ground, but they are often overshadowed to such an extent by the rest of the top that very little growth will be made by the cion. Assuming that the top-working of the tree will be com-

FIG. 4.—Proper placing of grafts. Always set grafts as near the main trunk as possible in order to insure a large fruiting area at a low height from the ground. Compare with FIG. 3

pleted in two years, in all cases enough of the tree top should be removed to furnish light to every graft. (Two years' time for completing a tree is recommended, for reasons given later.)

The placing of grafts should be done with a picture of the future top-worked tree in mind. The grafts should be made as near the main trunk as possible; never at the tips of long branches which have elongated as far as they are likely to grow. Cions set at the ends of long poles can not be expected to develop a large fruiting area. Besides, there is always the trouble of sprouts which may grow out below the grafts and which must be grafted in their turn or be removed. (Compare Fig. 3 with Fig. 4.) The younger the tree, the fewer the limbs that need to be grafted and the easier it is to find limbs of desirable size near the trunk. Unless it be to remedy pollination problems, the top-working of large trees, though possible, is not to be recommended. The main limbs are so large near the trunk that poor unions of cion and stock would likely occur. The proper size of wood to graft on such trees is too far out and too high up. So many branches would have to be top-worked that the operation would prove very expensive.

While selecting limbs to topwork it is well to keep in mind the danger from sun-scald. Injury due to sun-scald on an unshaded stub is shown in Figure 5. Such injury not only destroys the growing tissue of the limb, but is rapidly followed by attacks of insects and wood-rotting organisms. Sun-scald might be expected to occur on any large area of a smooth-barked limb which is directly exposed to the rays of the sun, particularly during the first few hours of the afternoon. Although the larger limbs have thicker bark they are as likely to suffer as the smaller ones. The larger the limb the less curvature is presented to the sun, which means less reflection of heat and increased absorption. As a rule, the moderately large limbs which lean toward the north and northeast are most susceptible to this injury. These limbs are so located that the rays of the sun strike them at about a right angle during the hottest part of the day.

If we should attempt topworking the whole tree at one time a great deal of sunscald might develop. By completing the operation in one year, practically all the small limbs which bear leaves are removed, thus admitting all the sun's rays to the northward leaning branches. This is the principal reason for extending the task of top-working a tree over a period of two years. It is probably best that the work of the first spring be started on the northeast side, and about one-half of the tree topworked. The untouched limbs on the south side of the tree will shade the stubs which have been grafted.

Water sprouts may be expected to grow out in considerable numbers on the grafted limb. All of these sprouts that are so placed that they can furnish shade for the grafted stubs should be retained for the second and third season. The rest of the sprouts should be removed. The water sprouts that are left for shade should be

tipped back. This will cause them to branch and furnish more shade; at the same time their growth will be suppressed to the extent that they will not interfere with the growth of the cion.

FIG. 5.—Sun-scald on a grafted limb. Two well-placed water-sprouts might have prevented this injury until the cions were large enough to furnish sufficient shade

The topworking should be completed in the spring of the second year. From this time on the growth of the cions and the water sprouts, if properly handled, should furnish sufficient shade to the stubs. Limbs grafted in the second season lean toward the south and receive the sun's rays during the warmest part of the day at a very

acute angle. Consequently more heat is reflected and less is absorbed. These limbs will stand top-working with far less protection, and sunscald will not be a serious problem.

It is possible to distribute cions all around the head of a tree the first year by taking care to set them in shady places where little danger from sunscald results. If only one branch on a limb is grafted it is very likely that the cions and water sprouts will make much less growth the first season than they would have made if the entire half of the tree had been grafted at once. When the remaining limbs are grafted the second year, little protection from shading is afforded and the northward leaning limbs are likely to suffer.

Methods of Top-working

There are four methods by which it is possible to topwork a tree to another variety: namely, cleft grafting, whip or tongue grafting, bark grafting, and budding into water sprouts. Of the four, cleft grafting is by far the most important.

THE CLEFT GRAFT

The limb to be grafted should be cut squarely across at a smooth place on the limb. A sharp fine-toothed saw is very important in making the cut. A square cut is emphasized not for the reason that the "take" of cions will be any better, but because it favors complete healing of the stub. The limb should be sawed off at a point where the wood is straight-grained and free from knots. This is important in securing a straight, uniform cleft which must be had to fit properly in the cions.

A special tool for making the cleft has been designed. This tool, illustrated in Figure 6, may be purchased from some of the orchard supply houses, or it can be made by a blacksmith. The cutting edge is made concave so as to assure cutting the bark, particularly at the end of the stub, before the wood is split. A straight-edge tool would have a tendency to tear the bark, since the wood would split ahead of the knife, especially in wood of twisted grain.

It is noticeable in the diagram that the curvature is not uniform. This type is designed for stubs of different sizes. The smaller the stub to be split, the greater the degree of convexity (the smaller the radius of curvature) should be. If a topworking job is to be done where considerable uniformity in size of stubs will be found, a tool can be made with the radius of curvature of the cutting edge to fit the size of the stubs. If this tool is purchased from an orchard supply house, the chances are that it will have a uniform curvature of the cutting edge and for this reason will be suited only to stubs of a certain size. A tool that has only a large radius of curvature and is fitted only for large stubs, will split the smaller stubs with very little cutting of bark. It will act on small stubs much the same as a straight edge tool would act. A tool with only a small radius of curvature will crush and tear the bark on large stubs before splitting

begins. The most practicable tool for stubs of all sizes therefore is one which has a concave cutting edge of a steadily increasing radius. When using a tool of this sort (Fig. 6), holding the handle upward adjusts the cutting edge to the larger stubs, while holding the handle downward adjusts it to the smaller stubs. The cutting edge can be fitted to stubs of intermediate size by holding the handle somewhere near the level of the end of the stub.

As a general rule, cions cut to three buds will be of sufficient length for topworking. The top of the cion should be cut off about one-fourth inch above the top bud, the cut being made to slope away from the top bud. The lower cut should be made at least one and one-half inches below the lowest bud. This will allow sufficient space to make the bevel cut. The bevel cut shown on cions in Figure 7 should be started at or slightly below the lowest bud. Stored food reserves are more abundant in the neighborhood of buds and it is more likely that callus formation, which is necessary in grafting, will be greater if the cut is started near the bud. In making the bevel cut it should be the object of the worker to secure the greatest amount of cambial contact. This does not mean that the bevel

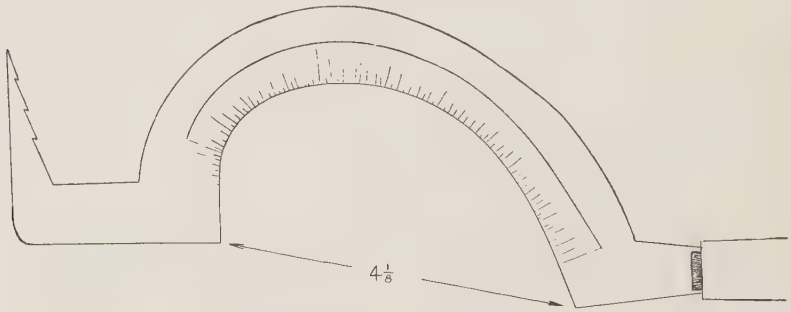


FIG. 6.—A grafting tool with a curvature of increasing radius. This tool can be adjusted to stubs of various sizes by raising the handle for large stocks and lowering it for small stocks

should be extremely long and drawn out to a pointed wedge. It is more often the case, where an extremely long bevel cut is made, that a minor irregularity in the cleft or on the cion will cause contact in a small area. When the contact surface between cion and stub is thus reduced, the cion is not held securely and may eventually blow out if a top is produced which presents considerable surface to the wind before sufficient graft union has been made.

The outer edge of the cion should be thicker than the inner edge, so that when the wedge of the grafting tool is removed from the cleft, the stock will clamp the cion in the region of the cambium. The lowest bud should be on the outside of the cion for several reasons. It places the zone of greatest callus production at a point where the callus can be most advantageously used both in the union of stock and cion and in the later healing of the stub. This bud if

placed on the outside has a good chance of developing into a limb with a strong crotch, thus adding much to the framework of the tree. (See Fig. 8) If the bud faces toward the center of the stock the limb will have to grow out over the stub, and as the limb increases in diameter it will exert pressure on the stub. This would not be considered desirable for the graft. The growth of a new limb will promote wood growth below it. This wood growth should be laid down on the outside where it will continually increase the strength of the union rather than laid down as callus on the inside where it will only tend to spread the cleft.

The bevel cut should be made straight and clean. The operator should in all cases avoid making a cut with a "wavy" surface. The surest means of making a uniform cut is to use a very sharp thin-bladed knife and make the entire cut with a single drawing of the knife. Poor contact of cion and stock due to irregular or "waving" surface of bevel is shown in Figure 9.

Skill in trimming cions comes only with practice. Experienced persons usually make the bevel cut by holding the cion in a horizontal position in the left hand with the tip under the thumb and the cion resting on the first two fingers. The lowest bud should be on the upper side. The knife is held in the right hand in a vertical position pointed slightly away from the body. From this position the first cut is made starting beside the lowest bud and proceeding to the end with one drawing cut. The cion is then rolled to the right between the thumb and fingers so that the basal bud moves 90 degrees, down. The left hand remains in the same position. The right hand assumes a horizontal position, with the back of the hand up, while the knife blade points to the left. From this position the second cut is made. Both cuts are made by drawing the knife toward the body.

FIG. 7. — Cions trimmed for cleft-grafting. Note proper location of buds. It is not necessary to bring bevel cut out to a thin point; such practice may be considered undesirable

After a cleft is made in the stub with the grafting tool, the tool should be pulled out, and the wedge on the outer end of the tool driven in the cleft near the center of the stub. This spreads the cleft so that the cion can be inserted easily and without much danger of tearing the bark away from the cambium. A prepared cion should then be set in each end of the cleft, and an effort should be made to insert the cions so that the cambium layer of cion and stock will be practically continuous.

The bark of the stock is much thicker than that of the cion. If the outer edge of the cion is set flush with the outer edge of the stock

and the difference in thickness of bark is disregarded, a small percentage of "takes" is likely to be experienced. (Fig. 10). Absolute continuity between the cambium of stock and cion is not essential to a "take", but contact so far as the unaided eye can tell is very desirable.

Some operators tilt the cion somewhat. This will insure cambial contact, since the cambium of the cion must cross that of the stock at some point. There are good reasons, however, why tilting should not be considered an ideal practice to follow. If the bevel cut on the cion was not made perfect, tilting is dangerous since there may be no contact at the point where the cambiums of stock and cion cross. With perfectly trimmed cions a slight tilting is not likely to give trouble.

The effects of tilting at too great an angle may be compared to sawing off a fairly large limb back to a very small lateral and leaving

Fig. 8.—In the case of this old graft a very strong limb developed from the basal bud of the cion. A strong crotch resulted. Compare with Fig. 19.

a short stub projecting. In all grafts the wood grain changes its course according to the highest point of contact between stock and cion. When cions are properly set this point is at the very rim of the stub; with tilted cions the wood grain turns toward the cion well below the top of the stub. The tissue of the stub above the union either dies or turns downward toward the union. The healing of the stub is very slow and a swelling develops at the base of the cion. The downward pointing tissue of the stub does not unite directly with that of the cion and in extreme cases enough pressure is exerted against the cion to cause breaking out.

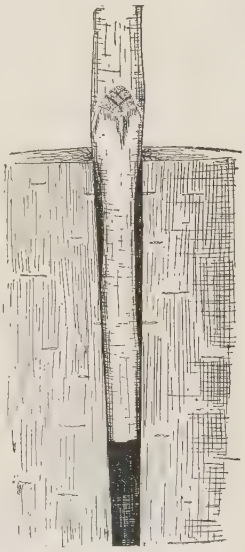


Fig. 9. — Cleft graft showing poor cambial contact, due to waving or irregular surface of bevel cut on cion. This may be the cause of many failures

The cion should not be set any deeper in the cleft than the top of the bevel cut. Deeper setting of the cion will prevent the growth of callus on top of the stub and will delay or prevent entirely a complete union. (Fig. 11). If the cion is set high so that a little of the bevel cut is exposed above the stub, it is less injurious than if it were set too deep, provided these exposed surfaces are covered with grafting wax. If the stock is accidentally split so deep that enough spring is not found in the jaws of the cleft to hold the cion in place, it is still advisable to set the cion at the proper level and draw the sides of the cleft together with a strong cord tied near the top. This might cause a little girdling, but should not be removed before the end of the first season. A little girdling would not be injurious, and if the cord were removed early in the season, the growth of the cion would be likely to spread the cleft, giving a weak union. This mistake might also be corrected by sawing the stub off shorter and making another cleft. The advisability of which course to follow will depend on the nature of the stub below the point at which it was first sawed off.

As mentioned before, two cions should be set in each stub. If they both live and grow, one must be removed later, but for the first year or so the growth of both is needed to assure the proper healing of the stub.

After the cions have been inserted correctly, the wedge of the grafting tool should be carefully removed so that the cleft will clamp the cions in place. If the handle of the tool is worked up and down very slowly, the wedge will work up and out of the cleft without disturbing the position of the cions.

A thorough job of waxing should be given the graft at this time, all cut surfaces being covered with grafting wax. The brush wax,

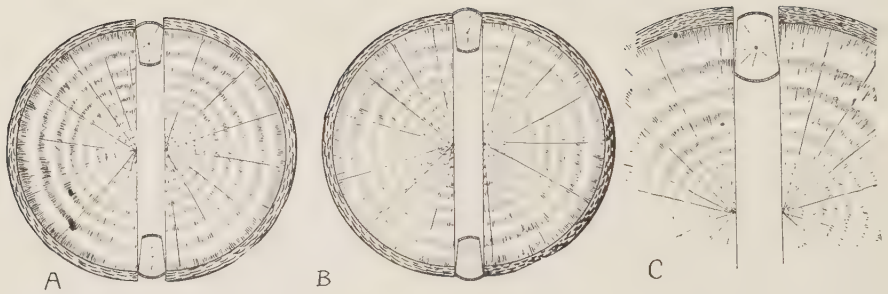


FIG. 10.—Cross sections of cleft graft showing why some grafts do not take. (A) Cions correctly set to secure cambial contact. (B) Difference in thickness of bark of stock and of cion has been disregarded, resulting in lack of cambial contact. (C) Lack of cambial contact due to excessive thickness on inner side of cion

discussed later, is recommended for this purpose. Waxing is done to prevent evaporation and the consequent drying out of the graft before union is made. It is necessary to exercise some care in waxing so as to prevent small air holes from forming near the cion, particularly in areas on top of the stub. The cleft on top of the stub between the cions should be thoroughly sealed, as well as the whole cut surface of the stub. Wax should be painted down both sides of the stub, sealing the cleft at least an inch below any visible split. The cut surface on the upper end of the cions should be well covered with wax.

THE TONGUE OR WHIP GRAFT

So far it has been recommended that only those limbs which measure one to two inches in diameter should be grafted. It is often very necessary, considering the future framework of the tree, that a cion be placed where a limb of this size is not available. If smaller limbs, one-fourth to one-half inch in diameter, are present, the tongue or whip graft method may be used instead of the cleft graft, and good results obtained. This method of grafting will be found quite useful if it is desired to topwork a number of young trees. As an example, if a grower wished to topwork a few three-year-old trees, the central leader might be cleft grafted and the side limbs whip grafted.

The results from whip grafting are better, the more nearly the stock and cion approach equal size. In cases where the stock and cion are approximately the same size, the whip graft might be superior to the cleft graft due to the quicker and stronger union obtained.

In making the whip graft, both the cion and stock are cut to match. A diagonal cut about 1¼ inches long is made on each. (Fig. 13.) These cuts should be made smooth so that no space is seen between them when the cut surfaces are matched face to face against each other. A slit is then made on both stock and cion by holding

the cut surface upright and bracing the upper side of the cut with the forefinger. The knife is then started about one-third of the distance from the "toe" (sharp end) to the heel, and made to run exactly with the grain, or cut across the grain slightly in the general direction of the heel. The depth of the slit should be approximately the same on both the stock and cion. This can be judged readily after several trials.

If the cion is smaller than the stock, extreme care should be taken to have the cambium of the cion and stock in contact with each other on one side. (No. 4 in Fig. 13.) If this is properly done, cambial contact is secured on three surfaces.

If, after uniting stock and cion, it is found that the toe of one projects beyond the heel of the other, the extension of the toe should be trimmed off. Failure to correct this condition will cause many grafts to heal slowly, or cause the point of the toe to die back. (Fig. 14.)

FIG. 11.—Although a union has been made and growth is proceeding, this stock will not heal readily, since the cion was set too deep in the cleft. This stock is really too small to cleft-graft

It was once a common practice to tie the whip graft with some sort of cord. This is no longer recommended. If the graft is properly set, waxing alone is sufficient. Many nurseries now employ this graft for topworking without tying. If tying is done it should be with a soft cotton string, which should be cut as soon as the graft is growing well. Failure to cut the string will cause girdling of the graft, which is usually followed by a slowly growing cion and a poor union.

As in the case of the cleft graft, a thorough job of waxing should be given the whip graft. Care should be taken to make every part of the cut surface air tight, including the cion tip.

THE BARK GRAFT

The bark graft should never be employed as a means of topworking a tree. It is described here because it is adapted for one particular purpose. The bark graft is preferred by some operators in-

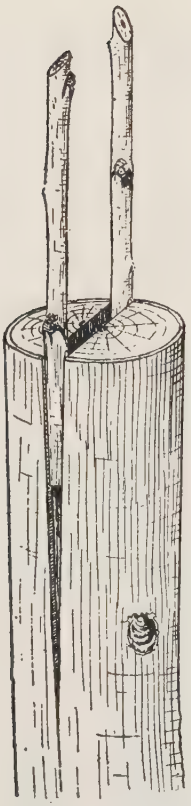


Fig. 12. — Completed cleft graft ready for waxing

stead of the cleft graft for the reasons that the percentage of "take" is likely to be greater and the method does not involve the splitting of the stub. The latter feature is said to induce more rapid healing and to permit the grafting of limbs that are too large to split. It is rather doubtful whether limbs that are too large to cleft-graft can be successfully grafted by any method. It seems to be quite well recognized by careful observers that bark grafts, particularly on large stubs, are blown out too easily by high winds. This fault is considered sufficient reason for not using the method for permanent topworking.

If it is necessary, as is often the case, to cut a large limb back to a side branch, a bark graft can be employed to prevent die-back of the heel. When a large limb is cut back to a side branch the heel of the cut is removed from the path of food translocation. Callus formation on the heel will be very slow if at all, and there is greater likelihood that the heel will die back and pave the way for wood-rot organisms. A bark graft inserted in the heel will furnish the callus for that side of the limb, while the side branch will cause the other side to callus. This cion should not be allowed to grow a heavy top; otherwise it may be blown out and the purpose for which it was put there defeated.

The cions for bark grafting can be trimmed the same way that was described for the whip graft, or they may be trimmed with a shoulder as shown in Figure 15 (page 2). The bark of the stock may be split and the corners folded back to insert the cion, or a chip of bark exactly the size of the cion may be removed from the stock. With this method of graft the cion will have to have some means of support to hold it in place. For this purpose two small wire brads will give good results. The bark graft should then be waxed in the same way as other grafts.

It should be remembered that the very fundamental considerations involving the union of the bark graft do not present the idea of a strong union. The union between stock and cion is made along the cambium of the stub. In the case of large stubs with little curvature the union grows almost entirely in one plane. When a wind of no great violence strikes the top of the cion at a right angle to the plane of union the result is too often disastrous (Fig. 16).

THE BUDDING OF WATER SPROUTS

Budding is a very common method by which nurserymen propagate known varieties on seedling stocks. Orchardists may employ

budding in topworking young apple trees and also use it to a limited extent on the water sprouts of older trees. These have been mentioned in connection with the prevention of sunscald. Greater emphasis might be placed on the proper handling of water sprouts. Too many people have the notion that all the water sprouts which grow out on a stub below the graft should be stripped off, leaving a bare pole supporting two small cions at the end. Some publications have left their readers under the impression that water sprouts are only consumers and have not emphasized the fact that they are also producers. It is not meant here that all water sprouts along the stub should be allowed to grow rampant; if they were, the cions would soon be shaded too much. There is a happy medium between the growth of the cions at the end of the stub and the growth of several well-spaced water sprouts along the stub.

Two or three water sprouts on a stub would serve the following purposes: (1) they would aid in the prevention of sunscald, especially if the limb grows toward the north or northeast; (2) they would assist in the "pull" of soil nutrients into the stub that has temporarily lost its top; (3) they would, to a certain degree, prevent temporary starvation of the stub and its roots for those organic food materials which are manufactured by the leaves; (4) they would furnish excellent one-year-old wood as the stock for late summer budding or early spring whip grafting.

In the latter case, it should be decided by the operator whether the grafts, which were set in the spring, will supply sufficient top to the tree or whether a few of the water sprouts should be budded in late summer or whip-grafted the following spring. In either instance it is well to remember that the topworking of a few of these water

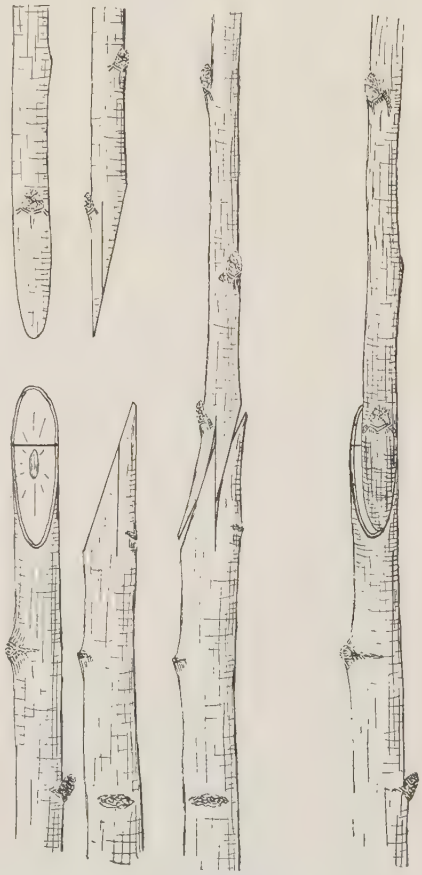


FIG. 13.—The whip or tongue graft. (1) and (2) on left show cions and stock cut to match. (3) Cion placed on stock. (4) Cion, smaller than stock, set to one side to get cambial contact

Fig. 14.—When a cion is not fitted properly on a stock, such imperfect healing as this must be expected

sprouts affords an excellent opportunity to keep the top of the tree low.

There are a number of methods of budding which are, fundamentally, all the same. For the purpose at hand, shield or T-budding is best. Budding in West Virginia should be performed the latter part of July or first half of August. At this time the bark on the stock still slips and peels easily.

The buds are obtained from the variety to be propagated, the buds in the axils of the leaves on the current season's growth being used. The buds should be well-formed, this being the reason for delaying the operation so late in the season. Bud sticks should be collected from moderately vigorous growth, 18 to 24 inches long. The leaves should be trimmed off, leaving about one-half inch of the leaf stem to facilitate handling the bud (Fig. 17). The bud sticks should then be wrapped in wet cloth to keep from drying out. When budding it is well to discard the first four or five buds at each end of the stick. These are usually less developed than the buds near the center.

Budding may be performed on stocks as old as three years with very good success. After the third year the bark of the stock begins to thicken too much for successful budding. In speaking of budding into the limbs of young trees or water sprouts of older trees, it is assumed that they come within this age limit. The limbs or water sprouts should be at least three-eighths inch in diameter in order to bud with ease.

A smooth area should be selected on the stock, as near the main branch as possible, to place the bud. Any intervening leaves or twigs should be rubbed off. The budder holds the stock with the left hand and at the same time makes a perpendicular cut about one inch long. This is followed by a horizontal cut across the top at right angles to the first cut, forming a "T" (Fig. 18). If this horizontal cut is made with a rolling motion of the knife, which should be held slightly slanting, the inner corners of the "T" cut will be raised in this operation. The bark should then be lifted slightly along both

edges of the perpendicular cut. Most budding knives usually have a thin bone scalpel in the end of the handle for this purpose.

The bud is then removed from the bud stick by starting the knife about one-fourth inch below the bud and drawing the knife upward and cutting slightly into the wood. The knife is then withdrawn and a horizontal cut made one-fourth inch above the bud and just through the bark. The shield-shaped piece of bark with bud and leaf petiole can then be removed without any wood attached. The bud should be inserted immediately into the "T" cut and pushed firmly into place. Wet raffia is the best material with which to tie the bud. Great care should be taken to wrap the bud securely from the bottom to the top of the perpendicular cut. The raffia should be tied at the end so that it will not loosen when dry. If the raffia comes loose it will be very likely that the cambium of the bud and stock will dry out and the bud will fail to set.

If the budding operation has been successful, the bud should have united with the stock at the end of two weeks. The leaf petiole will drop and the bud will have a plump and healthy appearance. The raffia should be cut at this time. This bud will remain dormant until the following spring. The stock should be cut off just above the bud before growth starts the following spring. Thereafter the bud should be given much the same care as is described for the graft in the discussion which follows.

Subsequent Care of the Graft

Much of the success in grafting depends upon the subsequent care of the graft. A few weeks after the grafting is completed all trees should be gone over, and defective waxing corrected. It should not be necessary completely to rewax a graft at any time. Callus formation will usually seal the sides of the cleft the first season. No

Fig. 16.—This tear may be expected when bark grafts are set in large stumps or limbs. Large limbs cannot be grafted successfully by any method

further attention need be given a cut surface after it is sealed with callus. In the case of the cleft graft the top of the stub might not completely callus over for several seasons. If the wax used was hard the growth of the cions may cause it to crack and crumble on the top of the stub. Fresh wax should be applied in such cases until the callus growth covers the top of the stub. Attention to the job of rewaxing is emphasized to prevent the entrance of wood-rotting fungi to the stock.

Pruning of the growth on the cion should be done with much care and forethought. It is sometimes advisable to pinch out the tips of the vigorous shoots about midsummer. This will cause low branching and have a tendency to keep the new fruiting area nearer the ground. Only the soft green tip is all that should be removed. Heavy pruning is not recommended for young grafts since it tends to delay fruiting much the same as in the case of young trees.

Fig. 17.—Bud sticks. Left shows current season's growth before leaves are removed. Right, trimmed bud stick with part of leaf petioles left to facilitate handling of buds

Of course, it was never intended that both cions of a cleft graft remain permanently. If both were to grow to full size a weak crotch would be formed (Fig. 19). The new wood formed by a cion as it increased in diameter would soon begin to press against that of the other, and splitting out would be likely to occur. Eventually one cion must be removed, but both are necessary the first year or so in order to keep the stub alive on all sides and to insure complete healing. On a stub one and one-half to two inches in diameter a growing cion will send enough food back into the stub to furnish callus formation on the side the cion is growing on. The lateral movement of food across the stub is very slow and before one cion could form callus all the way around the stub, wood rot would be sure to set in (Figs. 20 and 21). If a live cion is feeding the stock on both sides, all of the cambium around the edges of the stock will remain alive and the wood in the center of the stock will soon be covered with callus.

Since one of the cions is to be taken off ultimately, it is a decided advantage to keep the growth of the cion to be removed smaller than the other. This is easily accomplished by keeping one cion pruned

back while the other is allowed to grow. A cion kept small will furnish ample food to heal one side of the stock and at the same time will not leave a large wound when removed (Fig. 22). The subordination of one cion should begin the first summer and receive attention every year as long as the cion is retained. The smaller cion should be removed as soon as the bases of the two cions meet. In the case of a small stock and vigorous cions, this might occur at the end of the first season. In other cases it may take several years.

After all of the main limbs have been grafted, a considerable amount of growth may be expected from small branches left on the main limbs below the graft. The proper pruning of these branches is fully as important as that given the cions. They should be handled in much the same way as that described for water sprouts. They will serve the same purposes as were enumerated for water sprouts.

In many orchards it is very common to see recently topworked trees with their centers filled with a mass of vigorously growing branches and water sprouts. In such cases the cions are usually making about six inches of growth each year while the water sprouts and branches in the center of the tree are making about four or five times as much. These water sprouts and branches have an advantage over the cions from the very start in that there is a better connection between the conductive tissue of the main trunk and all growth from the main trunk than there is between the cions and the stubs into which they are grafted. This advantage will always be maintained unless the growth in the center of the trees is properly pruned. This growth from the main branches should be kept uniformly thinned out and headed back until the cions are well established.

If attention of this sort is given the tree, the cions will take the lead in growth the first season. From this time on the cions should not only maintain this lead but increase it rapidly. The suppression and removal of the growth from the old variety should be increased as the growth of the cions increases. Finally a point is reached where all remaining branches on the main trunk may be removed and all attention devoted to the new top. The number of years that it will take to change completely the top of a tree may vary from two to as many as five. It will depend largely on conditions for growth and the size of the tree.

The growth on young cions should receive protection against aphis and fire-blight. This protection should be given special attention the first year, when only two or three shoots are growing from a cion.

The most important reasons for the failure of many grafts are (1) lack of care in obtaining dormant cion wood with well-developed buds; (2) improper trimming of cion, resulting in an uneven or "waving" surface; (3) poor cambial contact between

FIG. 18.—Budding operation. (A) Front and rear view of bud removed from bud stick. (B) Inserting bud into T-shaped cut on stock. (C) Bud inserted, ready for tying. (D) Bud tied with moist raffia. (E) A good type of budding knife

stock and cion; (4) lack of thorough waxing; and (5) the erroneous idea that the job is completed when the graft is made.

Grafting Waxes

There are many recipes for waxes for protecting grafts and covering wounds upon trees. In Europe many clays and pitch waxes are in common use. In the United States the resin and beeswax waxes are most commonly used. The alcoholic waxes are used occasionally. The good results that are sometimes reported from the use of such materials as paraffin and ordinary fly paper should be regarded with

Fig. 19.—Showing an old graft where both cions were allowed to remain. This forms a very weak crotch. One cion should have been removed earlier

caution. Injury has been known to result from their use. Any material that occasionally gives good results indicates that it fills certain fundamental requirements under some conditions. The fact that it is not uniformly successful means that it possesses certain deficiencies which are of no importance under some conditions, but of decided importance under others.

An ideal wax should have certain qualifications. These are: (1) the wax should not contain any material that would injure live tissue, under any conditions, at its application strength; (2) the wax

should prevent evaporation from stock and cion and completely seal cut surfaces from wood-rotting fungi; (3) the wax should not crack in cold weather or run in hot weather; (4) the wax should possess enough elasticity to accommodate itself to the growth of stock and cion.

This ideal wax has never yet been introduced, but there are several waxes that meet these requirments well enough for practical purposes. A discussion of waxes in the horticultural literature of today is practically limited to four basic formulae which are referred to as brush wax, hard wax, hand wax, and alcoholic wax. These basic fomulae may be changed slightly at times to suit the particular season. For example, if grafting is done early in the spring with cold weather still lingering, the amount of tallow might be increased in the hard wax; if grafting is done later in the spring, with warm weather coming on, the amount of resin might be increased in this wax. The brush wax and hard wax are solid at ordinary temperatures and must be heated in the orchard while waxing operations are in progress. Hand wax and alcoholic wax are applied without being heated.

Brush wax is superseding other waxes in many orchards and is recommended for first consideration at the present time.

FORMULA FOR BRUSH WAX

Resin	5 parts
Beeswax	1 part
Raw linseed oil	¼ part
Lampblack or powered charcoal	½ part

The resin is melted, the beeswax added and melted, after which the linseed oil is added. The mixture is then removed from the fire,

FIG. 20.—Old grafts, showing slow healing and decay of stock. On the right, one of the cions was removed too early or failed to grow

FIG. 21.—A condition that develops from cases similar to those of FIG. 20. This limb was grafted twice. Wood rot organisms started to work in the upper graft before callus formation sealed the stub

and the powdered charcoal is stirred in a little at a time to avoid boiling over. As soon as the mixing is completed, the wax may be partially cooled to a point where it flows slowly but easily. It may be used at once. For large grafting operations it will be found convenient to make enough wax to complete the job, the hot wax being poured into shallow containers to a depth of about one inch, and allowed to cool. When the wax has thoroughly cooled and solidified it can be dumped from these containers by administering a sharp blow on the bottom. The wax can then be broken up into smaller pieces for use in the field heaters.

This brush wax is considered an improvement over the old hard wax. The chief improvement lies in the addition of the charcoal. Without the charcoal the wax is very sticky and strings out in long

threads at every stroke of the brush. The addition of the charcoal increases the heat absorption, which in turn increases pliability without causing the wax to run. With greater pliability, the growth of a graft is less likely to force the wax off in large masses.

The old hard wax formula is included here mainly to show the difference between it and brush wax. Hard wax has no merits over

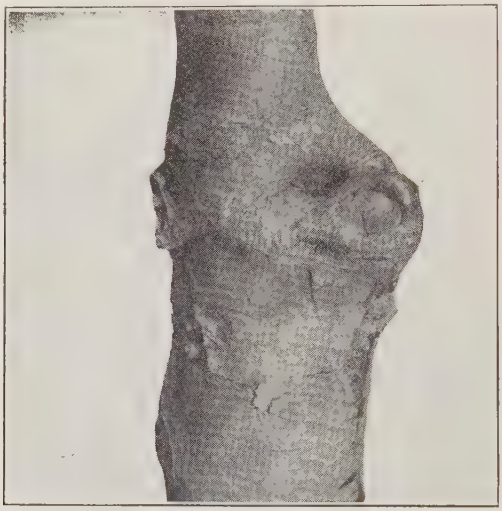


FIG. 22.—A good union of stock and cion. The temporary cion was kept smaller than the permanent one by annual heading back. A small wound was left by the removal of the temporary cion; such wounds heal over quickly

brush wax and its demerits are pointed out in the preceding paragraph.

FORMULA FOR HARD WAX

Resin	7 parts
Beeswax	2 parts
Tallow	1 part

Melt the tallow first, then add the beeswax and when this is melted add the resin. Boil slowly for 30 minutes. It can then be cooled by pouring into a container of cold water. The mass can then be broken up into small lumps for use in the orchard, where it is reheated and used much the same as brush wax.

For heating brush wax or any kind of hard wax in the orchard, an inexpensive outfit can be made. Obtain an 8-quart galvanized pail and remove the handle and rivets to the opposite end. Cut a round hole in the bottom so that a sauce pan six or seven inches in diameter will fit in to a depth of about three inches. This is the wax container

and this end of the pail automatically becomes the top. A peach basket bottom or other disk of wood is nailed in as the new bottom. Before nailing this in, a couple of flaps of sheet metal should be fastened in the center to act as a holder for the burner. A few holes should then be made in the side of the bucket for ventilation. Any type of small burner, kerosene or alcohol, may be used under the wax container. Two cans of "canned heat" will replace the burner and supply sufficient warmth under most conditions for about two hours. A small but constant flame is all that is necessary. If a high wind is blowing it may be necessary to shelter the heater in a box as the wind might cool the surface of the wax (Fig. 23).

A very satisfactory wax heater for orchard use is sold by some orchard supply houses. This heater is rather expensive but will pay for itself in one season if any amount of grafting is done. The heater is essentially a lantern much like the lanterns used by railroad men. The burner is modified to burn wood alcohol, and a pot, which contains the wax, is set down into the hood. This waxing lantern can be carried around and through the trees very conveniently. The flame is easily regulated. A very small surface of the wax is exposed to cooling by the wind. The flame receives almost perfect protection from the wind, and relighting is very seldom experienced. The only objection that one could offer to this lantern is the small amount of wax that the pot holds. This necessitates the frequent adding of wax, but waxing is very seldom much delayed on this account (Fig. 24).

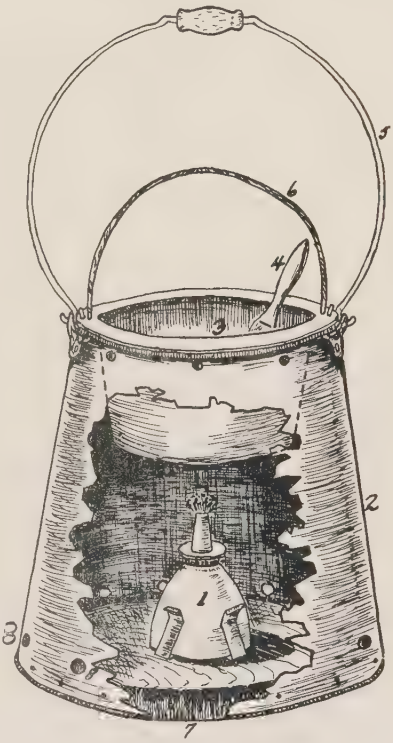


FIG. 23.—Home-made Grafting Pot

1. Alcohol burner
2. Inverted pail
3. Pan for wax
4. Wax brush
5. Replaced pail handle
6. Handle of wax pan
7. Wood cylinder base
8. Holes for ventilation

A one-inch paint brush is about the most desirable size to use in applying wax. The brush should never be allowed to rest on the bottom of the wax pot for any length of time. The heat will melt the glue at the base of the bristles and the bristles will pull out. This trouble may be avoided by driving a small nail in the handle of

the brush and bending it over in the form of a hook, to be hung on the rim of the pot. If the nail has been correctly placed the bristles of the brush will hang just above the surface of the wax.

If brush wax is used immediately after it is made there is some danger that the excess heat will cause injury to the live tissue. This is particularly true of the cions, which usually have thin bark. There is little danger of this in practice where either type of the wax heaters is in use.

Even with the improved methods of keeping wax warm in the orchard, some operators object to this task and prefer to use a cold wax. For this reason the hand wax is described.

Fig. 24.—Grafting lantern

FORMULA FOR HAND OR SOFT WAX

Resin	4 parts
Beeswax	2 parts
Tallow	1 part

This wax is prepared in the same manner as that described for hard wax. The only difference lies in the decreased amount of resin, which makes this wax pliable at the temperature of the hands. After the wax has cooled sufficiently in cold water, the hands should be greased with tallow, and the wax worked until it becomes a straw color and fine-grained.

The use of hand wax in the orchard, especially in cold weather, is not a pleasant job. The hands must be kept greased and even then they get sticky at times. This makes the change from waxing to other operations very awkward. If the weather is very cold, keeping the wax in warm water is a great help. Brush wax will be found to retain its good qualities longer than hand wax. Brush wax is applied more easily and quickly than hand wax and it leaves fewer air holes.

The use of alcoholic wax is another means used to avoid heating wax in the orchard.

FORMULA FOR ALCOHOLIC WAX

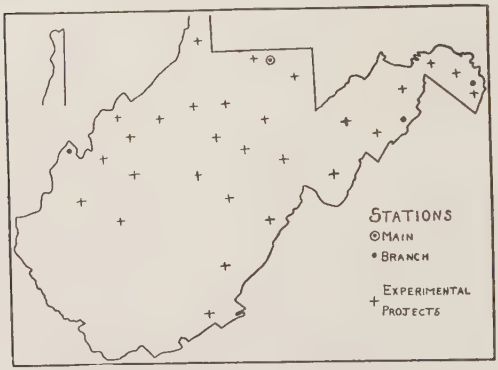
Pulverized resin	16 parts
Tallow	1 part
Wood alcohol	8 parts

Melt the tallow, then add the pulverized resin and heat until mixture is entirely melted. Remove from the fire and stir until partially cooled, then gradually add the alcohol until the cooled mass has a consistency of paint. The wax must be kept in some sealed con-

tainer like a fruit jar until ready for use. The wax is applied cold with a paint brush, and the evaporation of the alcohol leaves a solid residue.

It should be remembered that all of the ingredients used in these waxes are, to a certain degree, inflammable when melting and vaporizing. The fire used in melting the ingredients should not be intense. If the resin does catch fire it can be smothered by placing another pan in the one containing the resin.

AGRICULTURAL EXPERIMENT STATION



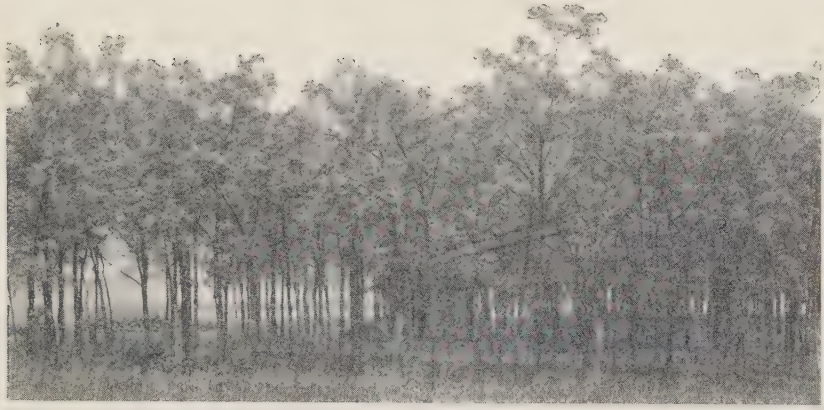
WEST VIRGINIA UNIVERSITY

ARIZ.UNIV.LIB. JAN 9 1931

CIRCULAR 58 DECEMBER, 1930

Save Black Walnut from Canker

BY C. R. ORTON AND J. M. ASHCROFT



A Healthy Stand of Black Walnut.
Unless canker-diseased trees are cut down, there may be no such timber left in the future (*Photo U. S. Forest Service*)

Go through your woodlot and look sharply for evidences of this new pest which threatens to wipe out your stand of Black Walnut ***unless effectively controlled***

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, DIRECTOR

Within the past year the attention of the Agricultural Experiment Station has been called to the occurrence in West Virginia of a new disease which has been described by the Department of Plant Pathology under the name of black walnut canker. During the past summer a study has been made of the distribution of the disease and the nature of the injury that produces the canker. Evidence from this survey indicates the existence of a disease which seriously threatens the culture of black walnuts. Although the study of the disease is quite incomplete, it seems desirable to bring such information as is available to the attention of the people of the state at this time.

DISTRIBUTION

During the summer of 1930 a survey of the counties of the state was undertaken to ascertain to what extent this disease of black walnut is distributed in West Virginia. Infection was found in the following counties: Monongalia, Marion, Preston, Taylor, Harrison, Barbour, Lewis, Upshur, Randolph, Braxton, Nicholas, Pocahontas, Greenbrier, Raleigh, Summers, Monroe, Mercer, and Fayette.

The map below shows the geographical location of these counties. It shows that the disease has already spread over an extensive area which forms a broad belt extending from the northern to the southern boundary of the state. The disease also extends southward into Virginia and northward into Pennsylvania.

Look out for catfaces on trunk or limb

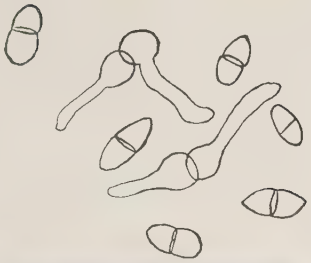
Counties in Which Canker Has Been Found

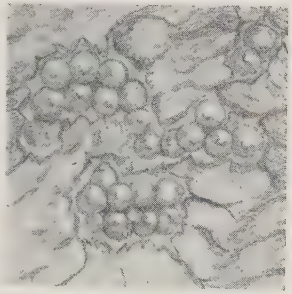
REPORT your discovery at once to your county agent or to the Department of Plant Pathology

Virginia

Counties in which survey work has not located the disease.

Morgantown,
West Virginia





Lower figure: Fruiting bodies as they appear on the bark (enlarged 60 times)
Upper figure: Spores of fungus, showing two germinating (enlarged 500 times)

DESCRIPTION OF THE DISEASE

The disease appears on the trunk, limbs, and branches of the tree as a rough, sunken canker characterized in the advanced stages by a number of concentric rings of callus. The figure in the upper right-hand corner is a photograph of a large canker on the trunk. As the canker grows larger, the heartwood is exposed, first at the center of the canker, but more and more as the infection area spreads. In the late winter and early spring, the organism believed to be responsible for the disease begins to produce spores, which are borne in very small, dark red, spherical, or pear-shaped fruiting bodies. These appear in little clusters, most frequently on the outermost callus of the canker; but they may also be found, often in abundance, on all the callus and even on the exposed heartwood.

The sketches opposite show the shape and appearance of the fruiting bodies, as well as the spores they produce. Both sketches exaggerate the true size.

The size of the cankers varies. Some as long as four feet vertically, and almost encircling the trunk, have been found. But they may be of any size between one as large as this and one four or five inches in diameter. The number of callus rings varies with the age of the cankers, between one and 18.

CONTROL METHODS

Spores are the means by which the disease is spread from infected to healthy trees. When the red fruit bodies have matured, the spores borne in them are forcibly discharged into the air, and are blown about by winds. If by chance any are blown to other walnut trees, infection of those trees may result. The spread of the disease can be checked by methods which prevent the production of spores.

Until further investigations have been made the following methods are recommended:

1. Trees with large cankers on the trunk should be felled and the cankerous parts cut out and burned. The remainder of the tree may be used for any purpose for which it is adaptable.

2. Trees on which cankers are confined to the limbs and branches may be saved by pruning. All infected limbs should be cut off well back from the cankerous parts. *The cankers should be burned.*

Fell the tree, cut out the cankerous portion, market the rest

3. Trees which are healthy except for small cankers on the trunk may be saved by cutting out the canker. The parts removed should be burned. This method is practical only with small cankers.

4. Treat all affected trees early in the winter.

In all cases where surgical methods are used in an attempt to save the tree, the wounds should be painted to prevent infection from wood-decaying or other disease-producing organisms. Any of the asphalt paints or white lead and linseed oil are recommended.

Blight has killed this Chestnut. Canker may do the same to Black Walnut unless checked at once (*U. S. Forest Service*)

LOSSES DUE TO CANKER

Black walnut wood is used in the manufacture of high-grade furniture and gun stocks as well as in the interior finishing of buildings. Its beauty and adaptableness for these purposes have made it one of the most valuable of our native forest trees. For this reason alone the destruction of our black walnut represents a considerable loss to the people of West Virginia.

The canker if allowed to follow its own course will eventually encircle the tree, and kill it. But long before this, in badly infected trees, the distorted condition of the trunk renders the tree worthless for lumber. So whether the tree is killed or not the result is the same.

An infected tree is a menace to all other trees near it. You can render a great service to your state, and at the same time increase the value of your walnut trees, by destroying the sources of infection.

ARIZ.UNIV.LIB. AUG 13 1931

CIRCULAR 59 JULY, 1931

West Virginia Weeds

BY H. K. ROWLEY

A roadside which has been permitted to grow up with weeds

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

CONTENTS

PAGE

Classification of Weeds 5

State Seed Law 5

Noxious Weeds Defined 5

Propagation of Weeds 6

Eradication of Weeds 7

Weeds Described

Bindweed, Black 11
Bindweed, Lesser 12
Carrot, Wild 13
Chickweed, Common 14
Chicory 15
Daisy, Ox-eye 16
Dock, Curled 17
Dodder 18
Foxtail, Green 19
Foxtail, Yellow 20
Grass, Crab 21
Grass, Goose 22
Grass, Quack 23
Garlic, Field 24
Galinsoga parviflora 25
Hawkweed, Orange 26
Mustard, Wild 27
Plantain, Buckhorn 28
Plantain, Major 29
Poison Hemlock 30
Ragweed, Common 30
Ragweed, Giant 30
Sand Briar (Horse nettle) 30
Smartweed, Pennsylvania 31
Thistle, Canada 32
Thistle, Perennial Sow 33
Thistle, Russian 34
Yarrow 35

*West Virginia Weeds**

by H. K. ROWLEY

LOSSES suffered from weeds are of various kinds. Weeds cause reduced yields by taking from the soil the nutrients and moisture so essential to crop plants. Weeds crowd and shade the crop plants, thereby depriving them of necessary sunlight. Weeds reduce the quality of crops. For example, quackgrass may send its underground rootstock through a potato, or field garlic in wheat makes it unsuitable for flour. Weeds adulterate hay and their presence results in a product much less valuable for animal feed.

Cultivation costs are enormous because of weeds. Burs from weeds get in the wool of sheep and greatly reduce the market value of the fleece. Mowing of pastures, roadsides, and fence rows is necessary in order to prevent further seeding of weeds, to improve unsightly property, and to give the crops a better chance to thrive.

The purpose of this circular is to help the farmer identify some of the more important weeds which may be present on his farm. A brief history of the outstanding growth habits is given in order to assist in methods of control or eradication of the weeds.† It is hoped that this circular will stimulate an interest in weed control and thus avert some of the enormous loss caused annually by weeds.

Some plants under certain climatic conditions may be important agriculturally but when grown under different conditions may be quite troublesome as weeds. Johnson grass, an important hay crop in the South, is an example. In West Virginia it is considered a noxious weed. For this reason a general definition which might satisfactorily explain the meaning of the term "weed" for the entire country is impractical. Neither can one accept the usual meaning

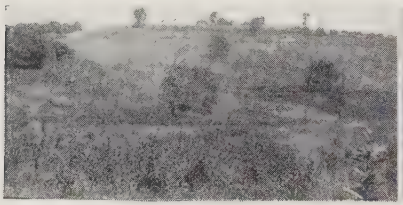
*Work reported in this circular was carried on cooperatively between the Agricultural Experiment Station and the State Department of Agriculture. Most of the photographs of the weed plants were made by W. E. Rumsey, state entomologist. The photographs of the weed seeds were furnished through the courtesy of Edgar E. Brown of the United States Department of Agriculture. The author is indebted to R. J. Garber, head of the department of agronomy and genetics, for suggestions in preparing the manuscript.

†The weeds discussed in this circular were chosen principally because they are among the most troublesome in the production of West Virginia field crops. Many of the common weeds are omitted. In the event the reader desires a more complete discussion on the subject he may consult such publications as Ada Georgia's book on weeds or Pammel and King's Weed Flora of Iowa, Bulletin No. 4.

of the term as applying to any of our agricultural plants, even though they may be growing where not desired. Wheat in West Virginia is not a weed even though it appears voluntarily in some other crop. For convenience, a weed in West Virginia may be described as any plant which has no economic value in the state.

Weeds are known to play a most important part in the spread of plant diseases. The cucumber Mosaic disease is harbored by ground cherry, horseweed, catnip, pokeweed, milkweed, and pigweed. In Mosaic disease of tobacco the following are known to be host plants: black nightshade, jimson weed, and buffalo bur. Such virus diseases may be transferred by insects from the weed host plant to the agricultural plant.

The presence of weed seeds in grain lowers quality. Cockle, when present in wheat to excess, produces a flour that is unfit for consumption. Wild onion bulblets give an unsavory flavor to flour. These undesirable ingredients must be separated from the grain—a process in which considerable grain also separates out and is lost. Buckhorn plantain seed in size and weight is much the same as red-clover seed. It can be removed only by machinery through a special, rather expensive, process. In addition a considerable portion of the clover seed is lost in the cleaning process.



A weedy pasture

A well-grazed, clean pasture

Some weeds when eaten by cows impart an unpleasant flavor to the milk. For example, ragweed or field garlic may produce an unpleasant quality in dairy products. During the dry season, when pastures are closely grazed, livestock often eat poisonous plants which may cause death. Whorled milkweed has caused severe losses in the West.

Certain weeds, among them poison ivy, cause extreme discomfort to man merely by contact. Some persons are very susceptible to the pollen of certain weed plants which cause hay fever. The pollen may be carried in the wind for great distances. When a susceptible person breathes pollen-laden air he may become a victim of hay fever.

CLASSIFICATION OF WEEDS

Weeds may be classified into three groups—annuals, biennials, and perennials.

Annual weeds may be divided further into summer annuals and winter annuals. Summer annuals grow from seed each spring and do not survive the winter. Ragweed is a summer annual. The seeds of winter annuals germinate in the late autumn, live through the winter, and mature the following season. Chickweed is a winter annual.

Biennial weeds produce their seed the second year, then die. The biennials require the first year to become established. This time is spent in root and leaf development. They usually form tap roots and the leaves are borne in rosettes. Wild carrot is an example of the biennials.

Perennials live for an indefinite number of years, surviving the severe winter weather by means of stored food in the roots, underground stems, or rootstocks and bulbs. Dock survives by means of a long tap root, quackgrass and Canada thistle by means of underground stems, and wild onions by means of bulbs.

THE STATE SEED LAW

In West Virginia the Commissioner of Agriculture is responsible for the enforcement of the seed law. One of the features of this law is the noxious weed seed clause, the purpose of which is to prevent the spread of certain destructive weeds. Because of their growth habits and modes of reproduction, noxious weeds have an advantage over agricultural crops, tending to depreciate the value of the latter by robbing them of water, nutrient materials, or sunlight, and by adulterating the crop, thereby reducing both yield and quality. The noxious weed seed clause provides that agricultural seed which is contaminated with noxious weed seeds shall not be offered for sale.

During certain seasons state inspectors sample the agricultural seed offered for sale in the markets of the state. These samples are forwarded to the State Seed Laboratory at Morgantown, where the seed is tested for germination and analyzed for purity. Seed which does not meet the state requirements is prevented from being sold.

NOXIOUS WEEDS

The Official Seed Analysts of North America have agreed that a noxious weed should fall under one or more of the four following classes:

(1) A persistent spreader through a system of running roots or rhizomes which rob the crop plant of food and moisture, interfere

with its growth, and make the weed itself hard to kill. In this class are such weeds as quackgrass and Canada thistle.

(2) A prolific producer of seed which may lie dormant in the soil for many years and thus insure perpetuation of the species. Wild mustard and buckhorn are good examples.

(3) Poisonous weeds, causing the death of animals or human beings. Weeds of this type should not be included with noxious weeds unless they are abundant and the seeds are carried in crop seeds.

(4) Parasitic weeds, causing the death of plants to which they attach themselves. Clover, field, or alfalfa dodders are plants of this type.

The West Virginia seed law in listing the noxious weeds groups these into two classes—primary and secondary.

Primary noxious weeds are quackgrass, dodder, Canada thistle, and perennial sow thistle. Seed containing any of these weeds in excess of one seed in a five-gram sample (approximately 1/6 oz.) cannot legally be offered for sale. However, the presence of secondary weeds does not prohibit the sale of seed in which they are found, provided their presence and the amount per ounce are marked on the tag attached to the seed container. Such secondary weeds are Johnson grass, wild onion, hawk weed, buckhorn, English charlock, oxeye daisy, Indian mustard, star thistle, wild carrot, and galinsoga. The total amount of all weed seeds present must not exceed three percent of the agricultural seed; otherwise sale is prohibited.

PROPAGATION OF WEEDS

Weeds are propagated by seeds and by vegetative parts of the plant, chiefly rootstocks, tubers, and bulbs.

SEEDS. Seeds are scattered by man, wind, water, and animals.

Man. Man is responsible for the dispersion of many weed seeds, especially for the introduction of weeds from distant localities and foreign countries. The manure resulting from consumption of weedy hay is hauled to fields, where the seed is permitted to grow. Imported hay has been responsible for the spreading of a number of weeds. It is thought that by this means Canada thistle has been introduced into the Eastern Panhandle of West Virginia. Hay containing Canada thistle seed was imported from Europe during the Civil War.

Grain fields are often permitted to become breeding places for weeds. The potato patch frequently is a hotbed for weed-seed production. After the potato vines die the weeds are often allowed to mature their abundant crop of seed before the potatoes are harvested. Seeds may also stick to the muddy shoes of man; threshers and uncleaned hay racks and wagon beds may carry weeds from

farm to farm. The questionable economic practice of scattering chaff from the barn floors for the purpose of reseeding meadows is responsible for the dissemination of many weeds.

Wind. Wind plays an important part in the distribution of weed seeds from field to field. Some seeds are especially equipped for flight by having attached long whorls of very light, hair-like structures termed pappus, which permit the wind to carry the seed for great distances. Canada thistle seed and milkweed have such a structure. Other seeds such as that of Russian thistle may be disseminated when the entire plant is blown from place to place.

Water. Water may carry weed seeds. In a freshet weed seeds are carried down hillsides. On flooded levels and down the streams seeds are carried to other fields.

Animals. Animals disperse seeds by carrying them on their feet when the ground is muddy. Seeds like burs may become entangled in wool or hair. Some seeds, especially equipped with barb-like structures which permit the seed to cling firmly to an object like wool, may be transported long distances. Birds eat weed seeds and fruits containing seeds. Some of them pass through the fowl's alimentary canal without affecting the viability of the seed. In this manner the weed seeds may become widely disseminated.

Rootstocks. Rootstocks are stems which grow under ground at various depths. At each joint or node the rootstocks are capable of sending out a new plant. Rootstocks continue to spread in all directions, forming a network of underground parts. After plants of this type are established it is not necessary that they produce seed in order to increase rapidly, since they are perennials. These plants are spread from small patches to all parts of the field during harrowing and cultivation. Canada thistle and quackgrass fall into this category.

Bulbs. A bulb consists of a leaf bud with fleshy scales. It is usually an underground part. Wild garlic is an example of a bulbous plant. Besides bearing seed, wild garlic produces two kinds of bulbs, the so-called hardshell and soft-shell bulbs. The latter usually germinate in the late summer or early fall, whereas the hard-shell bulbs remain dormant until the following late spring or summer, when they germinate.

ERADICATION OF WEEDS

Weed eradication has not been developed to a very high degree of efficiency. At present the methods used in eradication may be classified as follows: (1) prevent seed production by cultivation and mowing; (2) sow clean seed; (3) practice crop rotation; and (4) apply chemical sprays.

Prevention of seed production. The prevention of seed production is important in checking weed dissemination. A single pigweed may

produce thousands of seeds. Cultivation destroys the weed plants but it also tends to bring the weed seeds toward the surface of the soil, where germination is stimulated. Further cultivation destroys the seedlings. Hoeing goes hand in hand with the cultivator, especially on hilly land, where "checker board" planting is impractical.

The practice of harrowing the planted crop before it is up, or soon thereafter, with a spike-tooth harrow is an effective means of killing weeds. This operation destroys the seedlings, which otherwise may become well established by the time the agricultural crop is large enough to permit one safely to follow the rows with the cultivator. This harrowing operation may be continued in the potato field until the plants are 4 to 6 inches high. Plants of this size should not be harrowed early in the morning or at other times when they are turgid and easily broken. Often one must resort to pulling the large weeds in such crops as potatoes and in the garden in order to prevent promiscuous seeding. Mowing is useful to prevent seeding in pastures, fence corners, matured potato fields, and other places.

Summer fallow is practiced to subdue weeds. This has been done successfully in preparing fields for alfalfa. The land is plowed in early summer, and harrowings are made at intervals throughout the summer to destroy the weed seedlings. This treatment provides a fine seedbed for alfalfa.

The use of weed-free seed is an indispensable practice if one wishes to combat weeds successfully. Entirely too many weed seeds are sown with the agricultural crops. The state seed law was enacted to protect the farmer from the purchase of unclean seeds, but this protection is given only to those who exercise due care and purchase their seed from merchants whose supply of seed is checked by the state inspection service. Seed legally offered for sale must carry a tag stating the amount of weed seeds in percentage by weight. The law does not prevent seedsmen from offering low-grade seed. By carefully examining the tag the farmer may discriminate between good and poor seed, even though he is not trained to judge seed quality. Only seed of the highest quality, free from weed seeds, should be sown. Even the most rigidly practiced cultural methods will not keep out weeds if seeds containing weeds are sown. If farmers persistently demand clean seed the poorer grades of seed will soon disappear.

Crop rotation. A knowledge of the life history of weeds enables one to select a rotation of crops which will help destroy these weeds. Some crops have been used successfully to smother weeds. Such crops should be given special attention in the way of seedbed preparation and quality of seed used, since a smother crop to be successful must be established quickly and must hold its supremacy in growth. Soybeans and buckwheat may be used. Smother crops and crops which require intensive cultivation are sometimes included in a

rotation outlined to combat weeds. In eradicating wild garlic soybeans, corn, sorghum, millet, and potatoes are all good crops to use.

Herbicides. A limited amount of work has been done with chemicals in destroying weeds. Experiments with herbicides were carried on as early as 1895. Since then many chemicals have been used with varying success. The results of investigations with chlorates carried on during the past few years have been very encouraging. Chemicals, however, should be resorted to only as an emergency measure. Persons who are careless with their fields will find no comfort in experiments with chemical weed eradicators reported thus far. No chemical has been found which will mysteriously destroy all the weeds. The cost of chemicals that are effective is relatively high. Where cultural methods will hold the weeds in check, herbicides are not recommended. However, if there is a small infestation of Canada thistle, quackgrass, or other equally noxious weed, the most direct and efficient method of eradication should be used. Under such circumstances the use of herbicides may be the best remedy.

For several years iron sulphate has been used successfully in eradicating dandelion from lawns. It is used at the rate of 100 pounds to 50 gallons of water. Due partly to a difference in the leaf structure of dandelion and of cultivated grasses, iron sulphate destroys the dandelion but does not injure blue grass. A number of applications are required to produce complete eradication.

Other chemicals such as sulphuric acid, arsenate of soda, carbonic acid, and corrosive sublimate have been used, but the objection is that they are poisonous to livestock and, moreover, are too costly to be used extensively. Common salt has been used considerably, but it is only moderately successful unless applied in large quantities, which in turn renders the soil unfit to support plant life for a year or more.

For effectiveness as a herbicide in the eradication of perennials, a chemical should meet the following requirements:

(1) It must penetrate the soil to the depth of the underground root system.

(2) It must decompose slowly enough so that when it reaches the underground root system it is still effective.

(3) It must decompose or leach out of the soil in time to permit normal crop production within a reasonable length of time.

(4) It must destroy the roots of the weed.

(5) It must be effective in small quantities, and cheap enough to permit its practical use.

The chemicals which come nearest to meeting these requirements are the chlorate salts of potassium, sodium, and calcium. It has been found that they will eradicate successfully bindweed, Canada thistle, and quackgrass when applied in sufficient quantities.

CHLORATES

The chlorates are usually applied in the form of a spray solution dissolved in water. They may also be spread dry on the ground. The spray solution is formed by dissolving one pound of the chlorate salt in one gallon of water. The solution may be sprayed on with a knapsack sprayer or potato sprayer, depending upon the area to be treated and the equipment at hand; or the solution may be sprinkled on the plants in the infested area with an ordinary sprinkling can. Thoroughness of the job is important in this operation. All plants and the entire soil surface must be covered. At least two and sometimes three applications are necessary to kill quackgrass. The rate of application should be around 150 gallons per acre. The time of application has not been definitely determined. However, experiments show that it is not necessary to apply the solution on the growing plant. Applications made on infested soil containing the roots, even though the foliage and stems are dormant or dead, have been found effective. It has been recommended that the spray should be applied during the blooming period of the plant.

Experiments have been carried on at the West Virginia Station to determine at what stage of growth quackgrass should be sprayed. Plots of similar size and of like degree of infestation of quackgrass were treated at the rate of 250 gallons of sodium chlorate per acre. Fifty plots were laid off. Ten plots were sprayed in June and ten in December, each receiving only one application. Twenty plots received double applications. Ten were treated in June and October and ten in December and April. There was very little difference between the December and June treatments. The June-treated plots which averaged a 78.5% stand of quackgrass before the applications were made, had an average stand of 49.7% after treatment. The December treated plots averaged 81% before and had a 41.2% stand after the treatment, whereas the double applications gave far better results. In the June and October treated plots the stand of quackgrass was reduced from 79% to 5.2%. The December and April plots were reduced from 79% to 2.8%. The results of this experiment indicated that single applications of a 10% solution of chlorate were not successful in controlling stands of quackgrass, regardless of the time of application. On the other hand, double applications were very successful, whether applied in June and October or in December and April.

Extreme caution should be exercised in spraying with sodium chlorate. When the water of the solution has evaporated, the salt remaining will form a highly inflammable mixture with fine particles of organic matter such as lint from clothes or particles of dried plants.

Black Bindweed (*Polygonum convolvulus*)

Description: Black bindweed is an annual introduced from Europe. The leaves are deep green, long-pointed, heart-shaped, or spear-headed. The entire plant turns red in dry weather or as fall approaches. Flowers are small, greenish-white, borne in clusters of from 2 to 6. Seed resembles a buckwheat seed but is smaller and pointed at the end.

Propagated by seed only.
Time of bloom: June to September.
Time of seed ripening: July till frost.
Control: Sow clean seed and prevent seed formation by cultivation or close pasturing, as with sheep, or use intensive cultural methods to destroy seedlings.

LESSER BINDWEED (*Convolvulus arvensis*)

Description: Perennial (sometimes called morning glory); distinguished from the closely related morning glory (flower) plants by the name "small or field bindweed." The plant consists of many slender stems which trail on the ground, or they may climb on other plants or on fences.

Flowers are pink or flesh color, similar to cultivated species, but not nearly so large. Blooming continues throughout the summer. Seeds are dark brown, rough, pear-shaped, flattened on one side.

Propagated by seed and horizontal roots.
Time of bloom: June to August.
Time of seed ripening: August to September.
Control: Plant seed free of bindweed seed. Cultivation may

disperse rootstocks to various parts of the field. However, intensive cultivation holds the plant in check. Two or three applications of sodium chlorate at the rate of 250 gallons per acre will eradicate the plants.

Wild Carrot (*Daucus carota*)

Description: Biennial; first-year plant attains only a crown of green leaves borne on a taproot. Second year produces flowering stalks 1 to 3 feet tall. Flowers are clustered in large flat umbels, usually all white, although sometimes one in the center is deep purple. As the seed matures, the outer row turns in, forming a shallow, cup-shaped cluster. A bad weed in meadows and pastures.

Propagated by seeds.
Time of bloom: June to September.
Time of seed ripening: August to December.
Control: Sow clean seed. Cultivation is effective.

Common Chickweed (*Stellaria media*)

Description: Annual, or winter annual; spreading, creeping stems with a line of hair down one side. Leaves are ovate or oblong. Flowers terminal; each petal is cleft in its center, thus presenting a white star-like arrangement. A very troublesome weed especially in lawns and gardens.

Propagation by seed only.
Time of bloom: February to January.
Time of seed ripening: March to January.
Control: In the gardens and cultivated fields the weed may be controlled by intensive cultivation but, since this is impossible in lawns, frequent spraying throughout the year with iron sulphate at the rate of 100 pounds to a barrel of water is recommended.

Chicory (*Cichorium intybus*)

Description: Perennial, with deep roots. Stems are branching, leaves alternate, basal leaves spreading on the ground. Flowers are blue, some pink to purple.

Propagated by seed.

Time of seed ripening: August.

Control: Intensive cultivation will eradicate the plant from heavily infested areas. A few scattering plants may be controlled by pulling when the ground is soft or by cutting under the crown.

Ox-Eye Daisy (*Chrysanthemum leucanthemum*)

Description: Perennial; ox-eye daisy grows from 1 to 3 feet high. Stems often tufted. Grows from a strong thick rootstock.

Propagated by means of seed.
Time of bloom: May to October.
Time of seed ripening: June to November.
Control: Control may be effected by sowing clean seed and by cultural methods. Ox-eye daisy thrives in poor acid pastures and meadows where the soil conditions are unfavorable for clovers and blue grass. Liming and fertilizing the soil sufficiently for the tame grasses to thrive will drive ox-eye daisy from the fields.

CURLED DOCK (*Rumex crispus*)

Description: Perennial, stems 2 to 4 feet tall, smooth, few branches at top. Lower leaves are lance-shaped with wavy margins; hence the common name "curled dock". Flowers are borne at end of stems in branched clusters. Seeds when hulled are shiny brown and similar in shape to buckwheat seed.

Propagated by seeds and by shoots from the crown of the roots.
Time of bloom: June to September.
Time of seed ripening: July to October.
Control: Sow clean seed. Pull when ground is soft in spring. Cutting tap root does not kill the plant.

Dodder (*Cuscuta arvensis*)

Description: Annual; there are several varieties of dodder. Among the most common are field, clover, and alfalfa. They are pale yellow, slender, leafless, parasitic vines which spread profusely on the host plants such as clover and alfalfa. The plants develop from a tiny seed which is of a somewhat brown or buff color with a rough sanded-like surface. The young plant is nourished by means of its roots until it becomes entwined around its host plant. The dodder plant becomes detached from its roots and lives entirely upon its host by sending many saucer-like projections into the host plant. The dodder continues to thrive and develop seed. The flowers are pinkish white and are born in clusters along the stem. The leaves are inconspicuous scales.

The seed has been known to retain its viability as long as eight years while lying in the soil. Dodder is a noxious weed. The seed is carried in alfalfa and red clover seed.

Propagation by seed alone.

Time of bloom: June to September.

Time of seed ripening: August to October.

Control: Prevention is the most economical and satisfactory method of controlling dodder. Buy seed that is known to be free from dodder. If any dodder shows up in the field it is best to mow the infested areas and burn the plants. Spraying these mowed areas with sodium chlorate will destroy the plants.

Green Foxtail (*Setaria viridis*)

Description: Green foxtail is an annual grass 2 to 3 feet tall, depending upon growing conditions. Erect, sometimes branched, blades 3 to 10 inches long, one-fourth to one-half inches wide, rough on the margins, dark green. Spikes 2 to 4 inches in length.

Propagated by seeds only.
Time of bloom: July to September.
Time of seed ripening: August to October.
Control: Sow seed free of foxtail seed. Cultivation and cutting to prevent seeding controls it easily.

Yellow Foxtail (*Setaria glauca*)

Description: Annual; similar to green foxtail except that yellow foxtail branches more at the base and is more succulent. Spikes are more open, and seeds are larger. Heads and stems are yellow.

Propagated by seed only.
Time of bloom: July to September.
Time of seed ripening: August to October.
Control: Same as green foxtail.

CRABGRASS (*Syntherisma sanguinalis*)

Description: Annual; culms 1 to 4 feet long, creeping at the base and producing roots at the joints which touch the soil. Spikes 3 to 6 in number but sometimes more, arising from the summit of culm; purplish or reddish brown. One of our troublesome lawn and golf green weeds.

Propagated by seeds and by rooting at the joints.
Time of bloom: July to September.
Time of seed ripening: August to October.
Control: Prevent plants from maturing seed by means of hand cultivation, pulling, and destroying the plants.

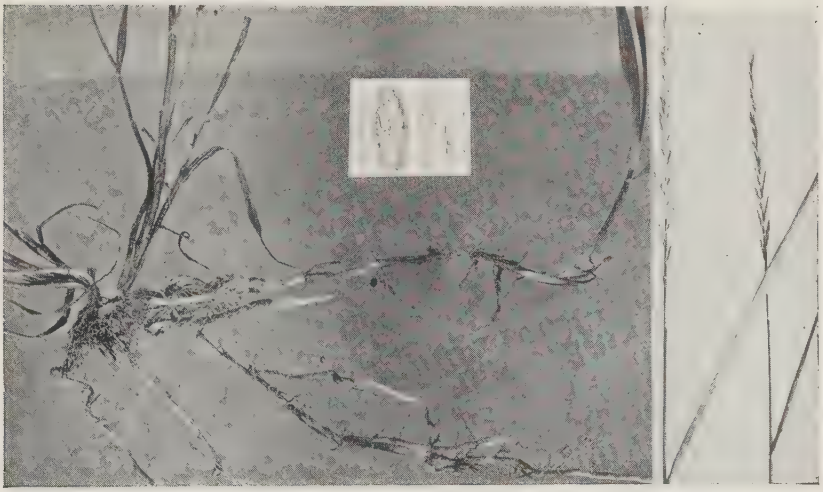
Goose Grass (*Eleusine indica*)

Description: Annual; erect, or spreading grass. Common in lawns, golf greens, and gardens.

Propagated by seed.
Time of bloom: July to October.
Time of seed ripening: August to December.
Control: Since goose grass is an annual and is propagated by seed, control may be effected by cutting or pulling the plants to prevent seed formation.

QUACKGRASS (*Agropyron repens*)

Description: Perennial, with stems and leaves typical of grasses, ranging in height from 12 to 40 inches when mature, according to conditions in which the plants grow. The plant has an extremely strong underground system of rootstocks. The rootstocks have short, stiff points capable of penetrating hard soil. The quackgrass rootstock will completely penetrate a potato tuber.



Propagation by seeds and rootstocks. Quackgrass spreads rapidly to all parts of a cultivated field. The harrow and cultivator break the rootstocks and scatter them to different areas of the field where they become established and form a mat of plants.

Time of bloom: June.

Time of seed ripening: July.

Control: Unless the seed is entirely free of quackgrass it should not be sown. The destruction of an infestation of quackgrass is difficult. Spraying the infested area two or three times with sodium chlorate at the rate of 250 gallons per acre is the most satisfactory method of destroying the plants.

Field Garlic (*Allium vineale*)

Description: Field garlic (commonly spoken of as wild onion) is a perennial, 1 to 3 feet tall, rising from small bulbs. Leaves are slim, deep green, hollow. Flowers are borne in a dense umbel in the top of a slender flowering stalk.

Propagated by bulbs produced underground and by bulblets borne on top of flowering stem; rarely by seeds.

Time of bloom: May to June.

Time of seed ripening: Seed seldom formed. Aerial bulblets ripen same time as wheat.

Control: The eradication of wild garlic is difficult. It reproduces by means of three kinds of bulbs. Two kinds which are produced in the ground differ in that one is a soft bulb which germinates in the summer or early fall; the other is a hard bulb. A few of this kind may germinate in the fall, but most of the hard bulbs do not germinate until the following spring. The aerial bulblets are produced in clusters on top of the stock. These methods of reproduction insure a continuous increase of plants, unless vigorous methods of eradication are adopted.

The cultural method of control has been used successfully. The most successful schedule has been about as follows: plow the infested field in early fall and allow it to lie fallow during the winter. Freezing destroys the bulbs which are exposed to the weather. A thorough plowing is again made in early spring, followed by intensive cultivation such as is ordinarily given to crops like corn, sorghum, potatoes, or soybeans planted in rows. Again in the fall and the following spring the land should be plowed as before, followed by another season of intensive cultivation. This method practiced for three years in succession is usually successful in subduing wild garlic.

Other methods of eradication have been tried. Creosote oil (crude carbolic acid) kills the tops and ungerminated bulbs, but carbolic acid, because of its poisonous nature, is disagreeable to

handle. Its use on a large area is too costly. The use of motor crank-case oil when sprayed on the plants once each year has been found successful. It is strained and thinned with kerosene in order to permit the use of a knapsack sprayer. The application should be made around the middle of April, before the heads of wild garlic form.

Galinsoga (*Galinsoga parviflora*)

Description: Annual. Stems 1 to 2 feet tall, pale green, slender, many branches. Flowers nearly ¼ inch across, white with yellow centers.

Propagation by seed.
Time of bloom: June to November.
Time of seed ripening: July to December.
Control: Prevent seed from maturing by proper cultural methods.

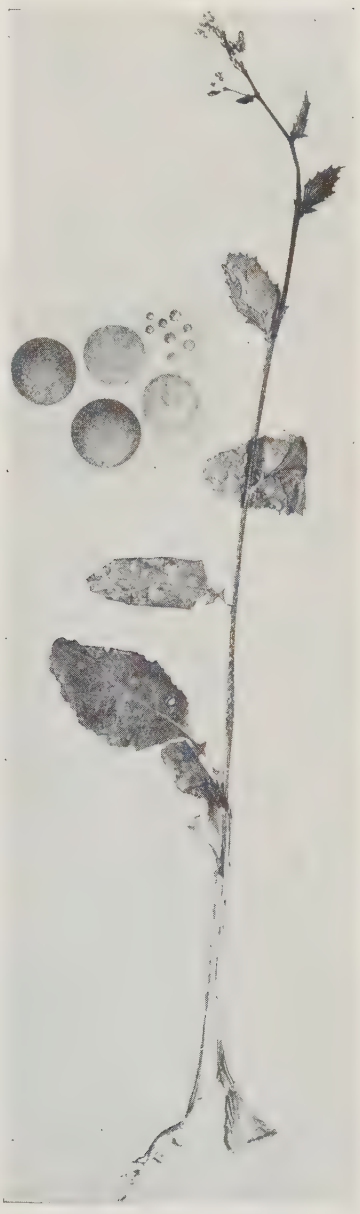
Orange Hawkweed (*Hieracium aurantiacum*)

Description: Perennial; stems 6 to 8 inches tall, unbranched and without leaves, heavily covered with black hairs. Basal leaves form a rosette, covered on both sides with stiff hair, making them unpalatable to animals. Flowers are brilliant orange-red, about an inch across. Seeds are equipped with a row of bristled hairs which permits the wind to disperse them widely.

Propagated by seed and underground rootstocks.
Time of bloom: June to September.
Time of seed ripening: July to October.
Control: Intensive cultivation will destroy this weed, but in pastures it presents a real problem. The use of chlorates to date has not been reported but it is probable that such chemicals would control it. Salting has been reported satisfactory in some cases.

Wild Mustard (*Brassica arvensis*)

Description: Lower leaves are deeply divided; upper leaves are smaller. Flowers are yellow and fragrant, clustered at the ends of the stem. Stems are one to three feet tall. Found frequently in feed oats shipped into West Virginia.



Propagated by seed only.

Time of bloom: May to September.

Time of seed ripening: June to October.

Control: Sow seed free of mustard seed. Prevent seed formation by pulling, or by spraying plants with iron sulphate solution, using 100 pounds of iron sulphate to a barrel of water.

Buckhorn Plantain (*Plantago lanceolata*)

Description: Perennial. The stem is closely set on a short, thick rootstock. A circular cluster of leaves comes out from near the crown. Leaves are narrow, lance-shaped, heavily ribbed, slightly hairy on both sides. Flowers are borne in spikes from 2 to 4 inches long on stems coming from the crown. The seeds are borne in capsules.

Propagation by seed only.
Time of bloom: April to October.
Time of seed ripening: May to November.
Control: Sowing clean seed is the most satisfactory method of controlling buckhorn plantain. Although intensive cultivation con-

trols the weed, this method does not prevent successive infestations, since buckhorn plantain seed may remain viable in the soil for many years and then germinate when conditions are favorable.

Broadleaf Plantain (*Plantago major*)

Description: A perennial commonly found in barnyards and lawns. Leaves are all basal, long-ovate, entire, obtuse, round at base, with 5 to 7 lengthwise veins which all draw together into a thick, channeled petiole. The outer row of leaves lies close to the ground and chokes out grasses and other plants. Flowers are on cylindrical, blunt spikes resembling a rat's tail. Seeds are small, irregular in shape, black, from 5 to 16, borne in a capsule. The seed when wet, like buckhorn seed, forms a gelatinous substance which aids in its distribution.

Propagation by seed only.
Time of bloom: May to September.
Time of seed ripening: July to October.

Control: Major plantain is easily controlled by cultural methods since destroying the crown destroys the plant. In lawns cutting the plant under the crown is the most successful method of control.

Poison Hemlock (*Conium maculatum*)

Description: Biennial with spotted leaves. Grows to a height of from 2 to 5 feet. All parts of the plants are poisonous to man and animal.

Propagated by seed.

Time of bloom: June to July.

Time of seed ripening: August to September.

Control: Poison hemlock should not be permitted to grow because of its danger to animals. It should be dug out by the roots.

Common Ragweed (*Ambrosia artemisiifolia*)

Description: Annual. The small ragweed is generally found in grain stubble fields and pastures. The other is the giant ragweed which may grow to a height of 12 feet.

Propagation by seed only.

Time of bloom: July to September.

Time of seed ripening: July and later.

Control: Ragweed is spread only by seed, and control can be effected by prevention of seeding. Ragweed seed lives in the soil for many years and will grow whenever conditions are favorable.

Giant Ragweed (*Ambrosia trifida*)

Description: Annual; commonly called horseweed. The giant ragweed produces long, straight, shaft-like stems. This ragweed is not considered a serious weed pest.

Propagation by seeds only.

Time of bloom: July or August.

Time of seed ripening: September.

Control: Same as common ragweed.

Sand Briar (*Solanum carolinense*)

Description: Perennial (sometimes called horse nettle) belonging to the same family as the potato. Stems are 6 inches to 2 feet tall, very erect and loosely branched. Sharp, prickly spines cover the stems and leaves. The blossom appears much like the potato blossom. The fruit when ripe is an orange-colored berry filled with straw-colored flat seeds similar to tomato seeds.

Propagation by seeds and rootstocks.

Time of bloom: May to September.

Time of seed ripening: July to November.

Control: Sand briar grows and spreads much the same as Canada thistle. Although troublesome especially in sandy light soils, it does not spread very rapidly in ordinary soils. Spray with certain chemicals has been reported successful.

Pennsylvania Smartweed (*Polygonum pennsylvanicum*)

Description: Annual, stems 2 to 5 feet tall, hard and woody when mature, branching and sprawling. Leaves are lance-shaped, from 2 to 10 inches long. Flowers deep pink color and frequently infested with a smut, causing head to have a purple color. Seed black, smooth, shiny.

Propagated by seed.
Time of bloom: July to October.
Time of seed ripening: August to November.
Control: Sow clean seed. Prevent plants from maturing seed.

Canada Thistle (*Cirsium arvense*)

Description: The plants grow to a height of 1 to 4 feet, depending upon conditions. Stems are erect, hollow, branching, with many flowers. Some stems bear staminate and others pistilate flowers only. The flowers are small, ranging in size from 1½ to 1¾ inches across.

Propagation by seeds and deep underground rootstocks.
Time of bloom: June to August.
Time of seed ripening: July to September.
Control: The most satisfactory method of keeping the fields free of Canada thistle is to sow seed free of the pest.

If a field becomes infested, rigid methods should be applied at once. Plowing, harrowing, and cultivating may serve only to break up the rootstocks and to drag them to other parts of the field, thereby increasing the infestation. Canada thistle may be eradicated if properly sprayed two or three times with sodium chlorate at the rate of 250 gallons per acre. Some farmers claim to have been successful in killing Canada thistle by growing alfalfa. The frequent cutting of alfalfa tends to subdue the weed.

PERENNIAL SOW THISTLE (*Sonchus arvensis*)

Description: Plants contain milky juice. Stems 2 to 6 feet high, leafy or bare on upper half, depending on competition of other plants. Leaves light green, large with coarse notches, slightly prickly on margins. Flowering head yellow, one inch wide, seeds reddish brown, 1/8 inch long, wrinkled.

Propagated by seed and rootstocks.
Time of bloom: June to October.
Time of seed ripening: July until October.
Control: Same as quackgrass and Canada thistle.

Russian Thistle (*Salsola kali-tenuifolia*)

Description: Annual. When young this plant appears very frail. It has long, slender, dark-green leaves and succulent stems, but when the seed begins to form, the leaves drop off and in their place appear sharp, scale-like leaves, with pointed bracts at the base. The stems turn woody rapidly. When the seeds are fully matured the main stems break off at the ground and the plant is blown from place to place over the fields, spreading its seeds.

Russian thistle ordinarily is not a serious weed in West Virginia, since it does not thrive well on moist soils.

Propagated by seed.

Time of bloom: July to September.

Time of seed ripening: September and later.

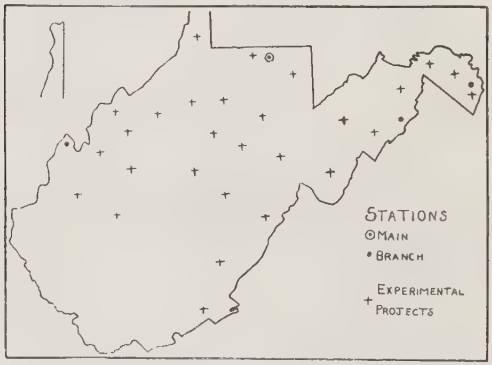
Control: Control may be effected by sowing seed free of Russian thistle seed. The weed is introduced into West Virginia most frequently through alfalfa seed which has been produced in the semi-arid districts, where the weed thrives.

YARROW (*Achillea millefolium*)

Description: Perennial; flowers borne in flat-topped, stiffly-branched, compounded corymbs; the heads are very small white or sometimes pink; rays and disk flowers, both fertile. Seeds are flattened, oblong.

Propagated by seed and rootstocks.
Time of bloom: June to October.
Time of seed ripening: August to November.
Control: Sow seed free of yarrow seed. May be pulled in loose soils. Proper cultural methods will eradicate the plants.

AGRICULTURAL EXPERIMENT STATION



WEST VIRGINIA UNIVERSITY

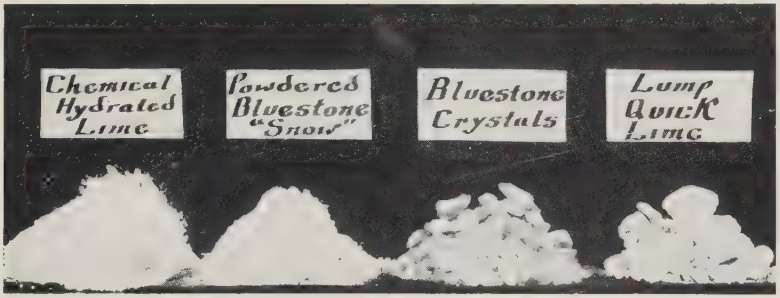
CIRCULAR 60 MARCH 1932

AGRICULTURAL EXPERIMENT STATION
COLLEGE OF AGRICULTURE, WEST VIRGINIA UNIVERSITY
F. D. FROMME, Director
MORGANTOWN

MAR 1 1932

Instant Bordeaux

by F. J. SCHNEIDERHAN



Types of bluestone and lime used to prepare Bordeaux mixture according to the new and old methods. Crystals of bluestone and quick lime in stock solutions have been used generally since 1885, while the use of powdered bluestone (snow) and chemical hydrated lime to prepare Instant Bordeaux is a more recent development

THIS circular describes a simple, rapid, and exact method of preparing Bordeaux mixture. The designation "Instant Bordeaux" has been coined to distinguish Bordeaux prepared by this method from that prepared from stock solutions. Seven years of study and experimentation have been given to the development of this method, which has already been adopted by many growers in the Shenandoah Valley apple belt and is rapidly replacing the old method of preparing Bordeaux from stock solutions of copper sulphate and quick lime. The technical data resulting from this study will not be included in this circular, which is intended as a brief description of the

new method of preparing Bordeaux. These data will appear in a later publication.*

HISTORICAL

In the grape-growing sections of France from time immemorial, it has been customary to apply verdigris (copper acetate) to grapes at the ripening period in order to prevent boys from stealing them. Millardet, the eminent French plant pathologist, noticed on one of his trips through the Medoc section in 1882 that grapes sprayed with verdigris developed much less infection by downy mildew, the most important disease of grapes in France. This accidental observation and the subsequent study of the toxic properties of copper, particularly of the combination of copper sulphate, lime, and water, resulted in what is known today as Bordeaux mixture (bouillie bordelaise) but originally known as "the copper mixture of Gironde". Space does not permit an adequate review of the early literature dealing with the improvements of Bordeaux. Millardet, Gayon, Gaillot, Patrigeon, Mach, the Duke of Bedford, and Pickering in Europe, and Butler, Jones, Warren, and Voorhees in America contributed largely to our early knowledge of this fungicide. It should be noted that Bordeaux mixture as used in the eighties and nineties of the past century contained much higher concentrations of copper than at present. As much as seven pounds of copper sulphate and seven of quick lime in 50 gallons of water were used at that time. The first important change to be made was the reduction of the copper content of Bordeaux, a tendency which has continued to this day. In 1910 the fruit growers in the Crozet section of Virginia used Bordeaux 6-6-50 to control bitter rot. At present the West Virginia and Virginia Orchard Spray Services recommend the 2-4-50 formula. There is also a tendency in recent years to increase the lime content in excess of that actually needed to react completely or to precipitate the copper sulphate. This increase in lime content has been made so as to decrease the caustic action of Bordeaux on leaves and fruit under certain weather conditions. In the United States, previous to 1906, when Cordley of Oregon and Piper of Washington demonstrated the effectiveness of lime-sulphur as a summer fungicide for apples, Bordeaux was practically the only well-known and widely-used fungicide. A glance at the spray calendars from the fruit-growing states will show that Bordeaux is now universally used as a warm-weather spray material, while lime-sulphur is used in the early spring, when cooler weather prevails. Bordeaux is the only effective and generally used fungicide for spraying potatoes, tomatoes, and other truck crops. In addition, it possesses definite repellent and toxic properties to insects, particularly the leaf hopper.

*Acknowledgment is made of the courtesy of the Virginia Agricultural Experiment Station in permitting the use of a part of the data contained herein, which were procured while the writer was a member of its staff.

CHARACTERISTICS OF GOOD BORDEAUX MIXTURE

Properly prepared Bordeaux is fine in texture, flocculent, gelatinous in appearance and to the touch. It has a high suspension ratio (slow to settle out) and does not deteriorate rapidly. Fineness of texture and gelatinous consistency are factors that determine the sticking and spreading properties which in turn determine to some extent the fungicidal effectiveness of this spray material. Color is an important indicator of good Bordeaux; the color should be a deep blue and not a greenish blue or a blue with a chalky subtone. The greenish color indicates an excess of copper while the chalky color is usually caused by an excess of lime.

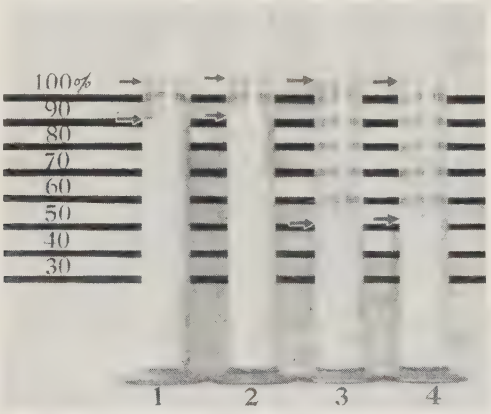


Fig. 1—A suspension test made with two Bordeaux mixtures prepared from different types of lime. The two graduates at the left contain Bordeaux 4-4-50 with a suspension percentage of 90 after two hours, while the two graduates at the right contain Bordeaux with a suspension of only 50%

The physical properties of Bordeaux mixture, particularly the ratio of volume of suspended material to total volume (the amount of settling out of the precipitate), are of paramount importance. Bordeaux that settles slowly indicates a proper dispersion of the component materials; this is the best criterion of judging its efficiency. Other factors such as temperature of water, concentration, and quality of materials being equal, it is now generally admitted that high suspension is correlated with high efficiency. Suspension tests are therefore the most practical and simple methods of determining the quality of Bordeaux. The rapid settling of Bordeaux may be caused by the presence of coarse lime particles, resulting from improper slaking, inferior lime, or faulty procedure in bringing the copper sulphate and lime into reaction. The difference between Bordeaux of high and of low suspension is shown in Figure 1.

PREPARING BORDEAUX MIXTURE FROM STOCK SOLUTIONS, AND SOME OF ITS DISADVANTAGES

Crystals of copper sulphate and quick lime have until recently been used in stock solutions to prepare Bordeaux. In practice the copper sulphate was dissolved at the rate of one pound per gallon of water. The quick lime was slaked and the resulting milk of lime diluted so that one pound of lime was contained in one gallon of water. The mixing of the proper amounts of these stock solutions and water resulted in Bordeaux. The equipment necessary for preparing Bordeaux varied from two barrels in which the ingredients were dissolved to an elaborate and specially constructed mixing plant as shown in Figure 3. The barrel equipment is shown in Figure 2.

If all the steps used in this method are followed carefully and high-grade materials are used, a very satisfactory Bordeaux can be prepared. There are, however, several inherent disadvantages and difficulties that have not only resulted in the production of inferior Bordeaux but have also caused a reluctance among growers to use this valuable fungicide. The main troubles lie in the non-uniform quality of quick lime and the care needed to slake it properly. Bordeaux made from improperly slaked lime contains gritty materials which clog the strainers and spray nozzles and cause delay and sometimes injury to leaves and fruit.

METHOD OF PREPARING INSTANT BORDEAUX MIXTURE

In this method stock solutions of copper sulphate and quick lime are eliminated together with all special Bordeaux mixing equipment. Instead of crystals of copper sulphate, powdered copper sulphate designated commercially as "snow" is used. Quick lime is replaced by superfine chemical hydrated lime known also as high calcium hydrate. It has been designated as "chemical hydrate" because it is used largely in the chemical industries. Pulverized copper sulphate has the approximate fineness of fine granulated sugar. It will dissolve in 1½ minutes when agitated in cold water. Superfine chemical hydrated lime is of a fineness such that 99.5% will pass through a 325-mesh sieve, and its approximate volume is 70 cu. in. per pound. The better grades of this lime contain from 70 to 73% of calcium oxide and from 69% to 70% of available CaO (calcium oxide). Experiments have shown that lime high in magnesium content (dolomitic lime) is not as desirable for Bordeaux making as that which is high in available CaO such as chemical hydrated lime. Powdered copper sulphate comes packed in barrels weighing approximately 400 pounds, and the chemical hydrate is sold in 50-pound paper bags.

The only equipment necessary for preparing Instant Bordeaux consists of a grocer's scoop or a small hand shovel, kitchen scales, and a few buckets. The simplicity of this method will be apparent from the following directions.

STEPS IN THE PREPARATION OF A 300-GALLON SPRAY TANK OF INSTANT BORDEAUX, 2-4-50 FORMULA

(1) Weigh out 12 pounds of powdered copper sulphate (snow) and 24 pounds of superfine chemical hydrated lime.
(2) Begin filling the spray tank with water preferably from an overhead intake pipe.
(3) When the tank is one-fourth (¼) full of water, start the engine and keep it running until one minute after the tank is full. When the water reaches the one-fourth-full mark (75 gal.), the powdered copper sulphate is either poured or scooped upon the intake strainer and washed into the tank by the inflowing water. The copper sulphate is quickly dissolved if the agitator works properly.
(4) When the spray tank is three-fourths (¾) full (225 gal.), the lime is added in the dry form, as the copper sulphate was, or else a paste is prepared with water of the consistency of cream and poured through the intake strainer.
(5) When the tank is full, the agitator is kept running one minute. The Bordeaux now is ready to be sprayed out.

It should be noted that the time required to mix a tank full of Bordeaux by this method is only slightly longer than that required to fill the tank with water. The agitator must run from the time the copper sulphate is added until one minute after the tank is full. This extra minute is usually sufficient to give the chemicals sufficient time for complete dispersion. If insecticides or other materials are used in combination with Bordeaux, they should be added when the tank is nearly full and while the agitator is running.

The preparation of Instant Bordeaux in traction spray outfits, although not as easy as in the power outfits, is nevertheless practicable. When the traction spray tank is three-fourths full of water, the outfit is put into motion by driving it, after which the proper amount of copper sulphate is poured directly into the tank, where it will be dissolved after a few minutes of agitation. The copper sulphate can also be dissolved by using a large, long hand paddle with which effective agitation can be obtained while the outfit is at a standstill. If the spray outfit is driven around the yard it should be filled with water after the copper sulphate is dissolved. Lime is added either in the dry form or in a paste after the machine is in motion and on the way to the orchard or garden. If the paddle method is used, the same essential procedure outlined for power sprayers should be followed. In actual practice it will be found that a good paddle properly handled will give as much agitation as can be obtained in the average traction sprayer; besides, it eliminates the pulling of the spray rig to obtain agitation.

ADVANTAGES OF THE INSTANT BORDEAUX METHOD OVER THE STOCK SOLUTION METHOD

The following advantages of Instant Bordeaux may be noted:

It eliminates the cost of special mixing tanks.

Slaking of quick lime, the main difficulty of the stock solution method, is eliminated.

Both the powdered bluestone and the superfine chemical hydrated lime can be stored indefinitely in a dry place. Quick lime must be stored in airtight containers; otherwise it will become airslaked.

The new method is actually cheaper in spite of the fact that powdered bluestone costs approximately one half cent per pound more than the crystals of copper sulphate. At present chemical hydrated lime sells for approximately $9.00 per ton at the factory, while quick lime sells for $8.00 per ton in bulk, or $18.00 in steel

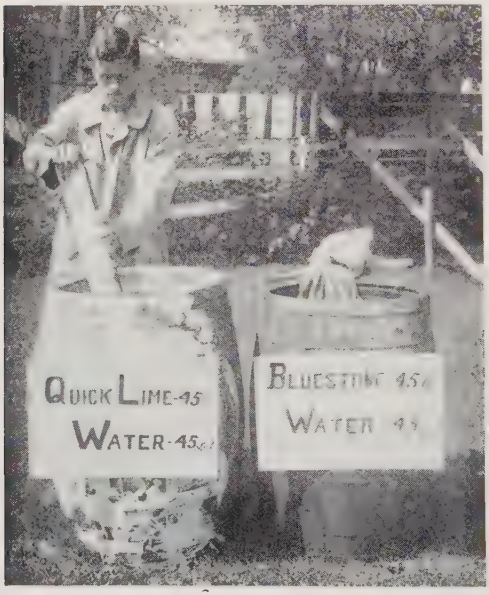


Fig. 2—A two-barrel outfit in common use in most orchards for preparing stock solutions of copper sulphate and quick lime. No provision is usually made for straining the milk of lime, and the open barrel containing the copper sulphate solution is a hazard to farm animals.

drums, the best way to handle quick lime on the farm. The cost of labor involved in dissolving the crystalline copper sulphate and slaking the quick lime is greater than the slight difference in the cost of the materials. Ordinarily a tankful of Instant Bordeaux can be prepared in three minutes; this depends, of course, upon the speed of the inflowing water. The extra cost of running the engine during the mixing process is not considerable.

Since the quality of quick lime is less uniform than that of the chemical hydrate, a more uniform quality of Bordeaux results.

Suspension tests with 30 formulas of Bordeaux over three-hour periods indicate that Bordeaux prepared from the powdered ingredients has a higher suspension percentage than that prepared from stock solutions of copper sulphate and the highest grade of quick lime.

If the directions given above are followed, there will be practically no clogging of nozzles, since the superfine chemical hydrate will not clog even the smallest-sized orifice of a spray rod or gun.

Fig. 3—A complete Bordeaux mixing plant. Water in the main tank in the center is piped to the side tanks, which contain the diluted stock solutions of bluestone and quick lime. These tanks are emptied simultaneously through a common opening which leads to the spray tank. Such special equipment is unnecessary when the dry powdered ingredients of Instant Bordeaux are used

DISEASE CONTROL WITH INSTANT BORDEAUX

One of the first questions a fruit or truck grower will ask about this new method of preparing Bordeaux mixture is whether the fungicide has the proper toxic properties to control fungous diseases. The toxicity of Instant Bordeaux has been tested during three years at Winchester, Virginia, in 1925, 1926, and 1928. In 1925 a block of Northwestern Greening heavily cankered by the fungus causing apple blotch *(Phyllosticta solitaria)* was selected for experimentation. The unsprayed trees (checks) had 66% of blotch, while the trees sprayed with Instant Bordeaux (2-4-50) in the three, five, and seven-weeks sprays had only 4% of blotched apples. In 1926 the same block of trees was again used, but different checks were selected. The weather conditions were such that blotch infection became very severe. The checks had 98% of blotched apples, while the trees

sprayed the same number of times and in the same sprays as in 1925 had only 5% of diseased fruit. The same operator and machine made the applications.

In 1928 another orchard of the same variety was used to test Instant Bordeaux alongside Bordeaux prepared from stock solutions of copper sulphate and quick lime. The checks developed 50% of blotch. The block sprayed with Instant Bordeaux, 2-4-50, in the three, five, and seven-weeks sprays developed only 3% of blotch, while the block sprayed with the standard Bordeaux of the same formula and on the same day with the same spray rig and operators had 4.5% of blotched apples, or 1½ times as much disease as where Instant Bordeaux was used.

Both fruit and foliage of all common apple varieties grown in the Shenandoah Valley belt have been examined over a period of six years for spray injury caused by Instant Bordeaux, the evidence being that under certain weather conditions, Bordeaux mixture prepared by either method will cause injury to fruit and foliage, but that under ordinary conditions Instant Bordeaux is no more caustic than standard Bordeaux.

It should be emphasized that it is very important to procure either regular or superfine chemical hydrated lime for the preparation of Instant Bordeaux. Ordinary plaster or so-called finishing lime contains too much magnesium oxide, which is not well suited for making Bordeaux. It is true that magnesium oxide will delay deterioration of Bordeaux, but calcium oxide is more essential because it is more directly involved in the reaction that results in the basic sulphates which make up Bordeaux. Ordinary agricultural hydrate is utterly unsuited for this purpose because it is comparatively coarse and contains considerable gritty material, which clogs spray nozzles. Similarly, finishing lime usually contains approximately 45 to 55% of calcium oxide and is considerably coarser than chemical hydrate, which as we have seen contains from 70 to 73% of CaO.

Any very fine lime having a high CaO content is satisfactory for preparing Instant Bordeaux. Hydrated lime, high in calcium oxide, is usually low in magnesium oxide. It is possible to prepare satisfactory Instant Bordeaux from finishing lime, but never from agricultural hydrate. The highest suspension tests were obtained from superfine chemical hydrate which was of a fineness such that 99.5% passed through a 325-mesh sieve. This hydrate contained 73.49% of calcium oxide, and only 0.86% of magnesium oxide. It is not always possible to obtain this superfine material. In that case a chemical hydrate of approximately the following composition should be used whenever obtainable: calcium oxide 73%, magnesium oxide 1% or less; fineness should be such that at least 99.5% will pass through a 275-mesh sieve. The fineness of hydrated lime is very important in determining the texture and quality of the resulting Bordeaux.

630.72 W51 NO 223 254

a39001 007413134b